REINFORCED CONCRETE CULVERT DESIGN CRITERIA Sections 1.0 to 3.0 DETAIL CRITERIA Sections 4.0 to 19.0

Iowa Department of Transportation

Office of Bridges and Structures

Updated (03-05)

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1.0 Introduction

This manual is an update to the original manual “Reinforced Concrete Box Culvert Design Criteria” that was released in October 30, 1981. This manual is divided into 19 Articles and is a general design aid for designing and detailing culverts for the Office of Bridges and Structures, Iowa Department of Transportation.

Due to the large amount of variation that can be found in the field, the designer and detailer should use this manual only as a guide with the understanding that exceptions will occur due to soils, existing structures, drainage conditions, etc.

The AASHTO 1996 Standard Specifications for Highway Bridges, 16th Ed. with 1997, 1998 and 1999 interim revisions is used, with modifications that are shown in this manual.

Articles in AASHTO Standard Specifications for Highway Bridges are referenced in brackets { }.

2.0 General

Hydraulic and other requirements at the site determine the required height and opening area of the box culvert. Once the required height and opening are determined the selection of a single or multiple cell box is determined from the economics of the structure. See “Guidelines for Preliminary Design of Bridges and Culverts” for information on additional information on culvert design.

2.1 Plan Development [5/26/94]

The following summarizes the coordination of plan development between the Office of Bridges & Structures and the Office of Design.

Culvert projects should be developed so all the items necessary to complete the culvert work are included in the plan. The plans should be developed so they can be constructed entirely as a separate project. However, common borrow areas may be utilized for both structures and road plans. Extensions for resurfacing projects will also be developed as separate projects. After the plans are turned in, the Office of Contracts will decide whether to combine the projects into one contract or let separate contracts, depending on the quantity of work involved.

The procedures listed above are intended to provide items on the appropriate plans according to who is intended to perform the work. There may still be project specific coordination issues to be worked out by the Resident Construction Office.

3.0 Analysis and Design (Cast-in-Place) [10/30/81]

3.1 Analysis Assumptions

The culvert shall be designed and analyzed by the Strength Design Method (Load Factor Design).

It should be noted that some structures may be designed as culverts but by definition they are actually bridges (see Article 1101.03 of the “Iowa Department of Transportation Standard Specifications for Highway and Bridge Construction” for the bridge definition).

3.2 Loading for Box Culverts [11/10/93]

The Load Factor Design Method involves applying two types of loading conditions:

1. Factored loads for ultimate design capacity.

2. Unfactored loads for serviceability checks.

3.3 Materials

All culvert concrete is to be Class C [3500 psi (24 MPa)] compressive strength.

All reinforcing steel shall be grade 60 (400 MPa)

3.4 Mainframe Program

The mainframe computer programs SIGLBOX and MULTBOX as described in section 17.1 shall be used in the design of culverts.

3.4.1 Design Fill Heights

When running **SIGLBOX** or **MULTBOX** for a non-standard culvert, use whole foot dimensions except as noted in Table 3.4.1-1 for fill heights rounding up for 0.5 ft and greater and rounding down for less than 0.5 ft.

Table 3.4.1-1 Design Fill Heights

Fill Height	Design Height
1 ft. to < 2 ft. (300 mm to < 600 mm)	1 ft.(300 mm)
2 ft. to < 4 ft. (600 mm to < 1200 mm)	Lowest fill
> 4 ft. (1200 mm)	Highest fill

3.5 Placement on Bedrock {AASHTO 6.2.2}

Culverts as designed, by the mainframe computer program (SIGLBOX and MULTBOX), are not to be placed on bedrock. The rigidity of bedrock will change the distribution of stresses in the floor and sidewalls. If there is no other choice but to place the concrete culvert floor on bedrock, a special analysis is required. Other options include over excavation of the rock and placement of a granular blanket.

3.6 Dead Loads and Earth Pressures

Because of changes in specifications with regard to earth loading, the office has two different loading guidelines. Section 3.6.1 loading is based on the older specifications and was used in the development of the English single and twin culvert standards.

Section 3.6.2 loading is based on the newer specifications that were introduced in the 1993 interim of the 1992 “AASHTO Standard Specifications for Highway Bridges”. This loading case was used in the development of the metric culvert standards and English triple standard.

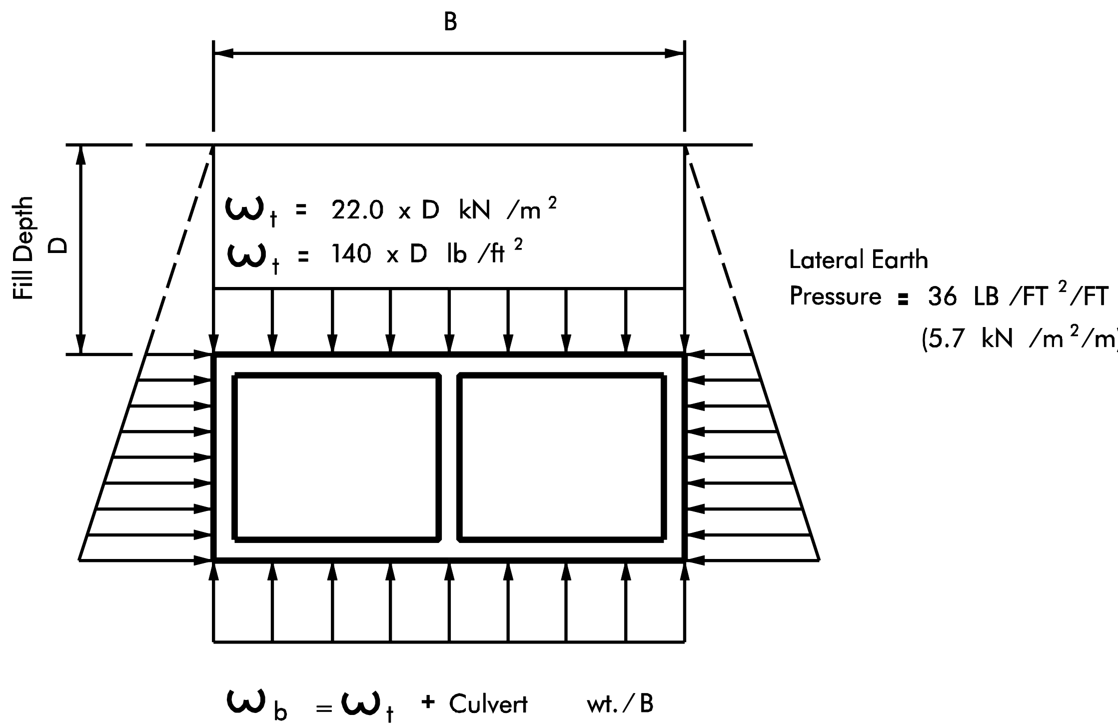
For non-standard designs where the culvert needs to be designed using the program SIGLBOX or MULTBOX, the engineer or design technician shall use the current specifications.

The unit reinforced concrete weight is taken as 150 lbs./ft^3 (23.6 kN/m^3).

3.6.1 Office Loading

The vertical earth pressure applied on top of culvert slab is computed as the soil weight of 140 lbs/ft^3 (22.0 kN/m^3) times the fill height in feet (meters). The lateral earth pressure applied on the exterior walls is taken as an equivalent fluid pressure of 36 psf per foot (5.7 kPa per meter) of fill depth. See Figure 3.6.1-1 for details.

ω_t = soil pressure
ω_b = soil pressure + culvert weight



ω_t = soil pressure
ω_b = soil pressure + culvert weight

Figure 3.6.1-1
Earth Pressure Detail

3.6.2 Current AASHTO Loading {AASHTO 6.2.1, 17.6.4.2}

The current 1996 AASHTO Standard Specifications for Highway Bridges, Article 6.2.1, specifies the following earth pressures may be used in the design of reinforced concrete box culverts:

Case 1:	Vertical earth pressure	120·Fe lbs/ft^3 (19·Fe kN/m^3)
	Lateral earth pressure	30 psf / ft (4.7 kPa/m)
Case 2:	Vertical earth pressure	120·Fe lbs/ft^3 (19·Fe kN/m^3)

Lateral earth pressure 60 psf / ft (9.4 kPa/m)

If these loads are used, the vertical earth pressure must be multiplied by a soil-structure interaction factor (Fe) that accounts for the type and condition of installation {AASHTO Article 17.6.4.2}. The soil-structure interaction factor (Fe) is not required to make service load serviceability checks. Unless otherwise noted in the soils report, the method of installation for the culvert shall be assumed to be the embankment method.

3.7 Live Loads [10/30/81] {AASHTO 3.7.4, 3.8.1, 3.8.2, 3.8.3}

List of Variables:

D = Depth of Fill
P = One Wheel load (P is distributed over the area of a square with sides equal to LD x WL)
ω = Distributed Load
S = Culvert Clear Span
EWL = Equivalent Wheel Load
LD = Longitudinal Distribution
WL = Wheel Line

Live load is limited to AASHTO wheel loads. Culvert supporting interstate highways shall be designed for HS20 or alternate military loading whichever produces the greatest stress {AASHTO 3.7.4}.

For fill depth of 3 feet (900 mm) or more, the live impact load is neglected. The following impact factor shall be used for fill depth less than 3 feet (900 mm) {AASHTO 3.8.1, 3.8.2 and 3.8.2.3}.

Table 3.7-1 Live Load Impact Factors

Fill depth [1 in. (25mm) minimum increment]	Impact %
0 to 1'-0 (0-300 mm) incl.	30
1'-1 to 2'-0 (325 –600 mm) incl.	20
2'-1 to 2'-11 (625-900 mm) incl.	10

The equivalent wheel load (EWL) shall be placed on the culvert the same as the wheel spacing specified in {AASHTO 3.7} to produce maximum effect in moments, shears, and reactions. The EWL will be in overlapping position, as shown in Figure 3.7-1, when the fill depth is more than 8 feet (2400 mm) for H loading and more than 2.29 feet (700 mm) for alternate military loading.

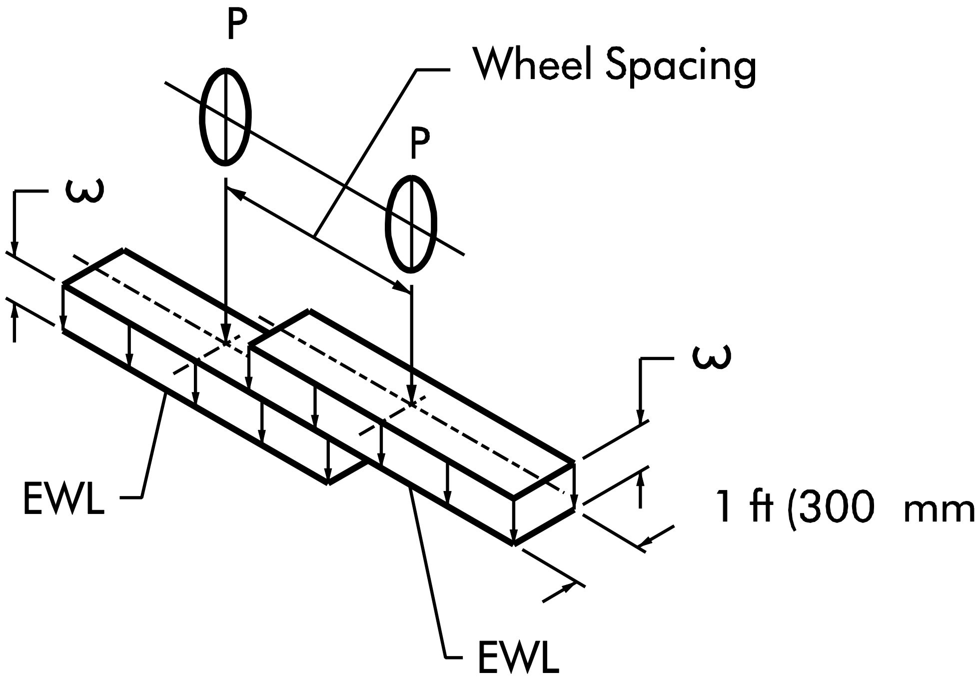


Figure 3.7-1
Equivalent Wheel Load

When the effect of live load is considered in design, a lateral live load pressure of 36 lbs/ft^2 (5.7 kN/m^2) (an equivalent of 1 ft (300 mm) surcharge of earth load) may be added to the lateral earth pressure. See Figure 3.7-2 for details.

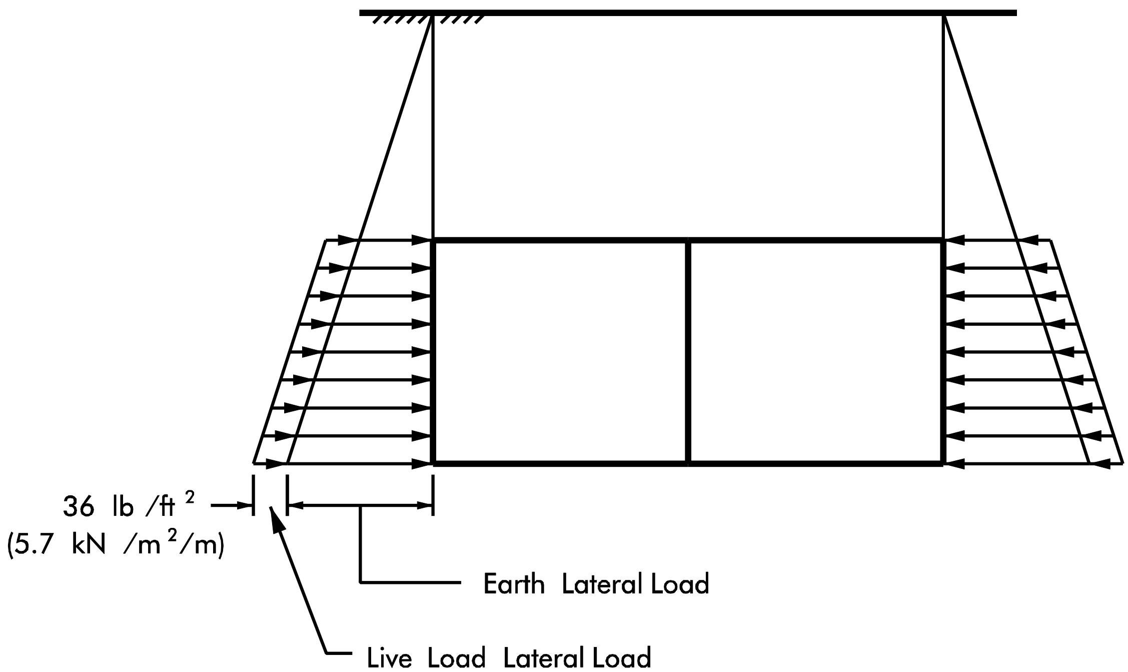


Figure 3.7-2
Lateral Earth plus Live Load Surcharge

As shown in article 3.7.3, 3.7.4, and 3.7.5 two trucks at passing position shall be used to determine the maximum live load effect. The live load distribution patterns on top of the culvert {AASHTO 6.4} are shown in articles 3.7.1 through 3.7.5.

3.7.1 For Fill Depths D ≥ 8 feet (2400 mm) and Culvert Clear Span Length

The effect of live load is neglected in design when the depth of fill is more than 8 feet and exceeds the clear span length of the culvert. For multiple cell culverts, the clear span length is the distance between the inner faces of the exterior walls {AASHTO 6.4.2}.

3.7.2 Fill depth D < 2 feet (600 mm) {AASHTO 6.4.2, 3.24.3.2} See Figure 3.7.2-1

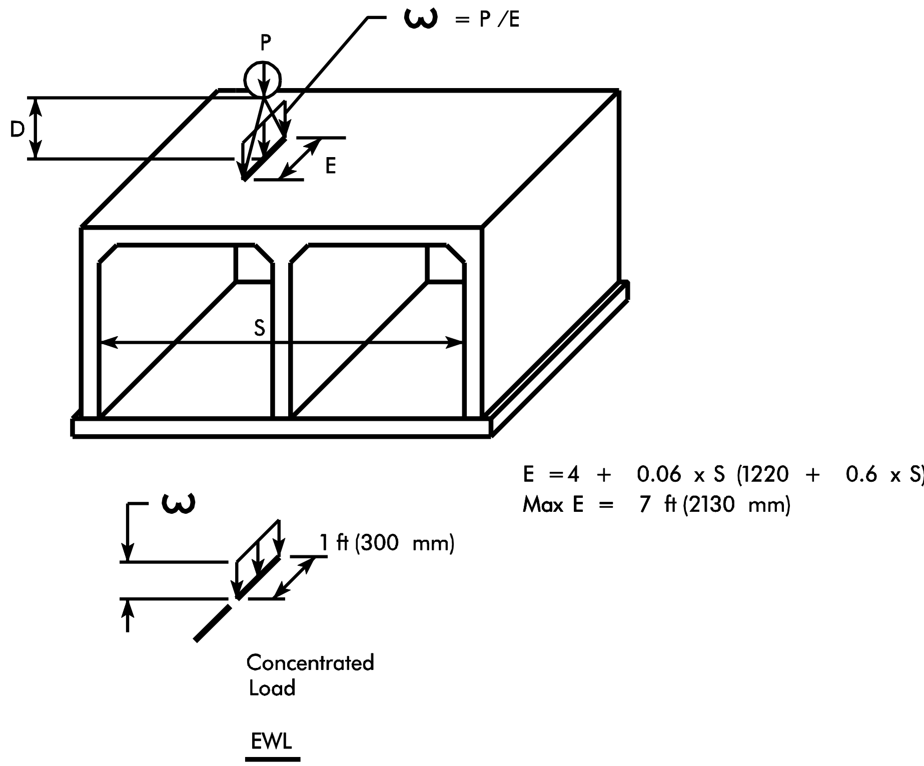


Figure 3.7.2-1
LL Distribution D < 2 ft. (600 mm)

3.7.3 Fill depth D ≥ 2 feet (600 mm) and D ≤ 2.28 feet (685 mm)

See Figures 3.7.3-1, 3.7.3-2 and 3.7.3-3 for details showing the distribution of live load. The 2.28 ft. soil depth was based on the following axle spacing.

(1.75 x 2.28 ≈ 4 ft. spacing between axles)
(1.75 x 685 ≈ 1200 mm spacing between axles)

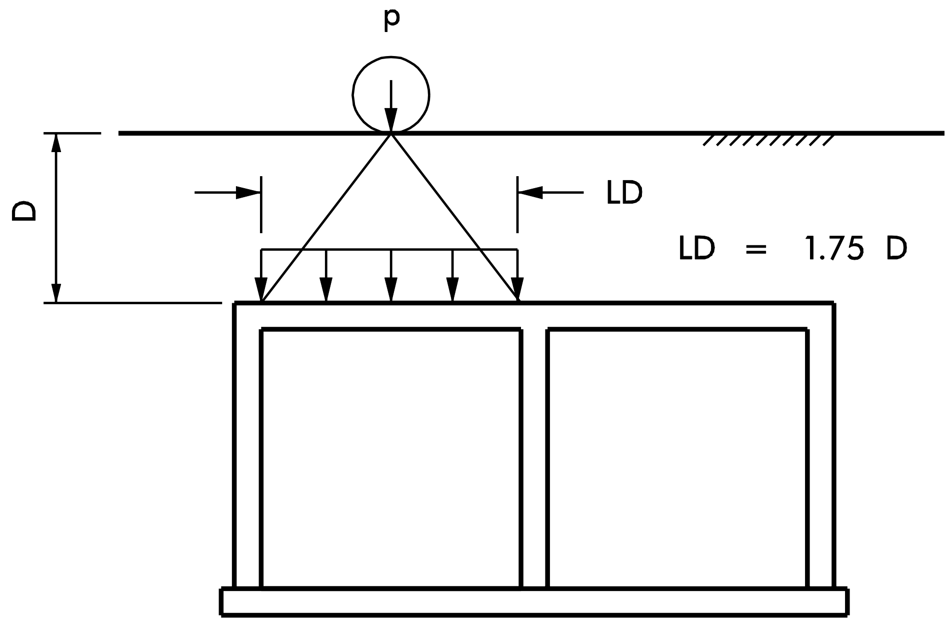


Figure 3.7.3-1
LL Distribution for Soil Depth 2 ft. (600 mm) ≤ D ≤ 2.28 ft. (685 mm)

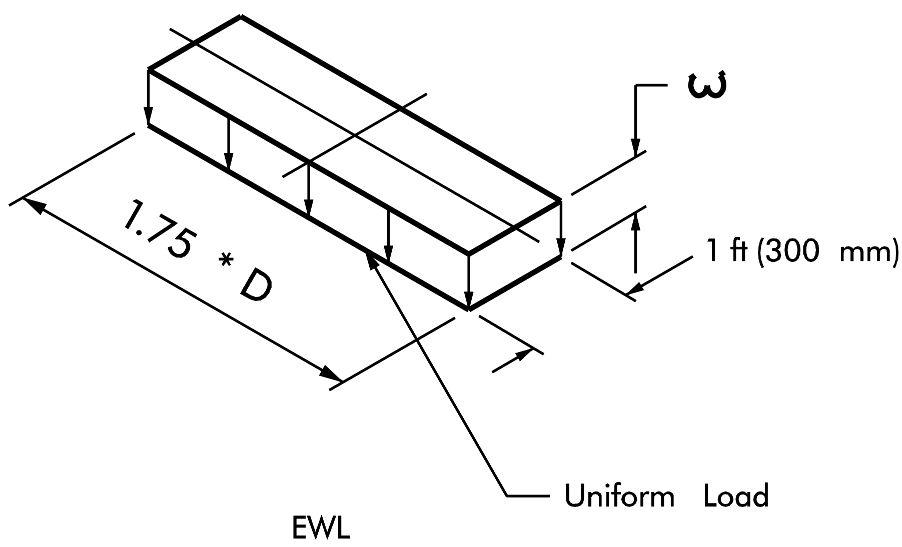
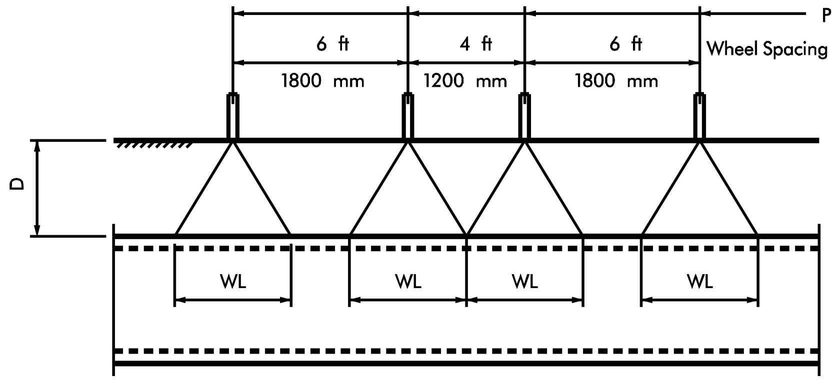


Figure 3.7.3-2
Equivalent Wheel Load



WL = 1.75 D

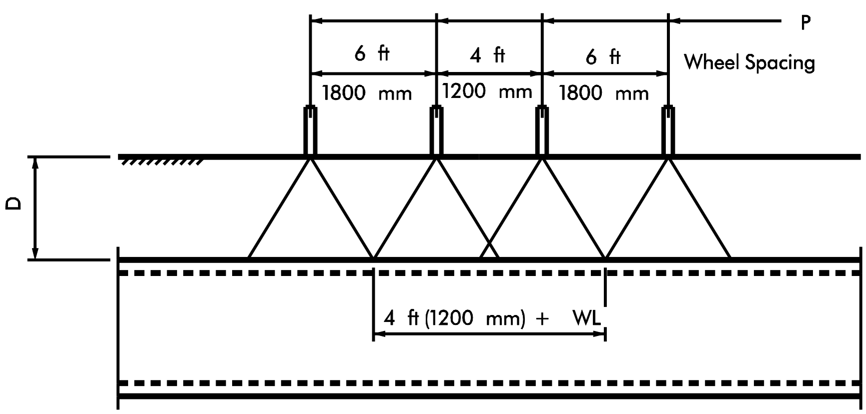
$$\omega = \frac{P}{(LD * WL)} = \frac{P}{3.06D^2} \text{ kips/sq.ft. (kN/sq.m)}$$

Note: ω is the unit load within LD per wheel load.

Figure 3.7.3-3
Longitudinal Section LL Distribution

3.7.4 Fill depth D > 2.28 feet (685 mm) and D ≤ 3.42 feet (1030 mm)

The soil depth was based on the following axle spacing.
(3.42 x 1.75 ≈ 6 ft, spacing between wheels of individual axles)
(1030 x 1.75 ≈ 1800 mm spacing between wheels of individual axles)

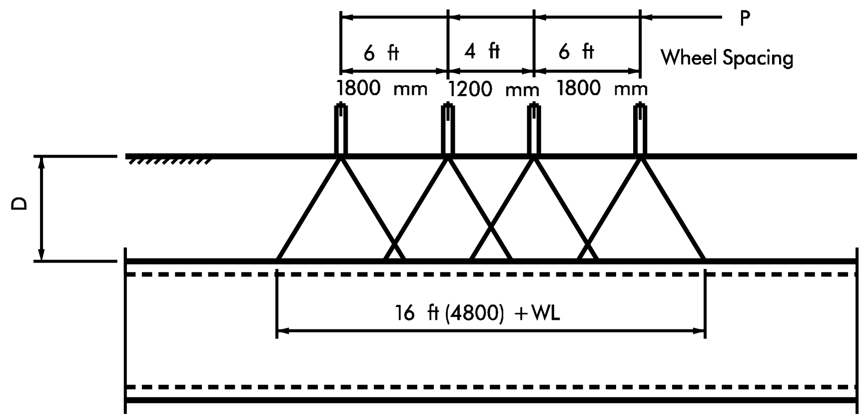


WL = 1.75 D

$$\omega = \frac{2P}{LD * (4 + WL)} = \frac{2P}{7D + 3.06D^2} = \frac{P}{3.5D + 1.53D^2} \text{ kips/sq.ft. (kN/sq.m)}$$

Note: ω is the unit load within LD per wheel load.
Figure 3.7.4-1
Long. Sec. LL Distribution- Fill Depth 2.28 feet (685 mm) < D ≤ 3.42 feet (1030 mm)

3.7.5 Fill depth D > 3.42 feet (1030 mm) and D < 8 feet (2440 mm) or span length {AASHTO 6.4} whichever is greater.



$$\omega = \frac{4P}{LD*(16+WL)} = \frac{4P}{28D+3.06D^2} = \frac{P}{7D+0.765D^2} \text{ kips/sq.ft. (kN/sq.m)}$$

Note: ω is the unit load within LD per wheel load.

Figure 3.7.5-1
Long. Sec. LL Distribution- Fill depth 3.42 feet (1030 mm) < D < 8 feet (2440 mm) or span length

3.8 Analysis Assumptions

3.8.1 Frame

The box culvert shall be analyzed, as a rigid frame with all corner connections considered rigid.

3.8.2 Sidesway

Sidesway is not considered in analysis.

3.8.3 Section Properties

The centerlines of slab, walls, and floor are used for computing section properties and dimensions for analysis. Standard fillets as shown in Figure 3.8.3-1, which are not required for moment or shear or both, shall not be considered in computing section properties.

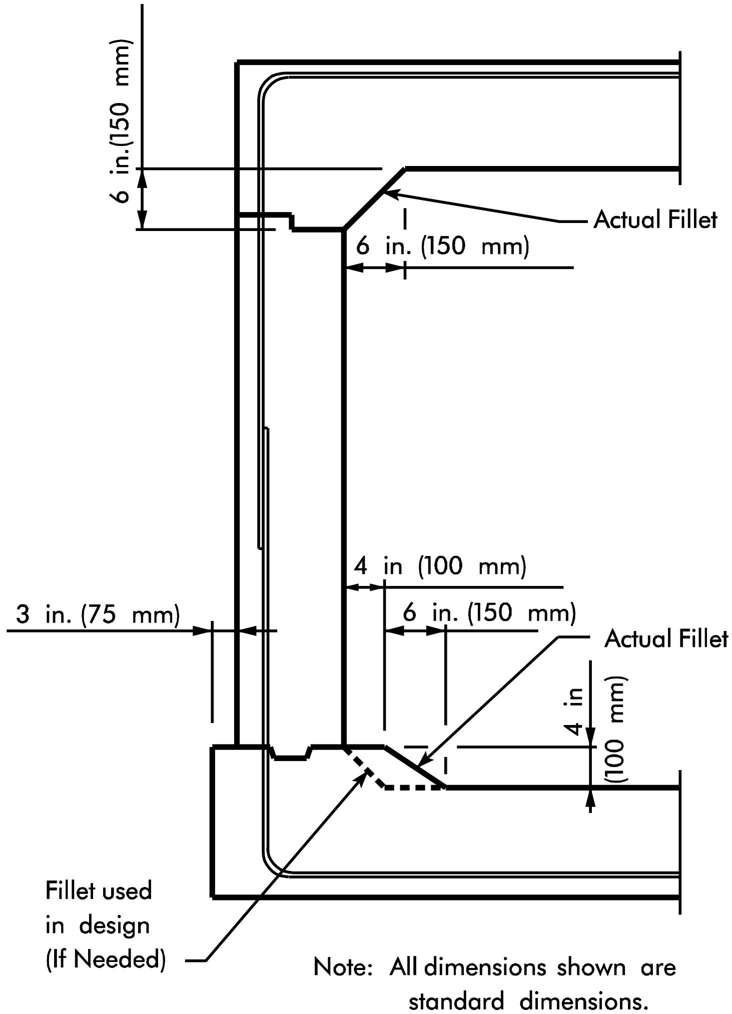


Figure 3.8.3-1
Typical Barrel Section

3.8.4 Load Distribution to Culvert Bottom

The culvert dead load and vertical earth load is assumed distributed uniformly over the bottom of the culvert. Soil pressure from vertical live load is assumed to have a distribution pattern similar to the stress pattern of a beam section under direct load and bending as shown in Figure 3.8.4-1.

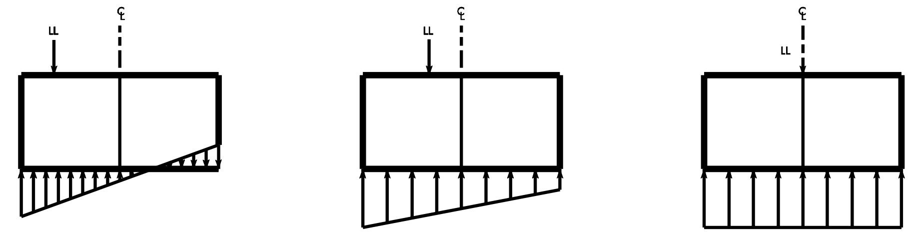


Figure 3.8.4-1
Live Load Distribution on Culvert Bottom
The resultant of the soil pressure must keep the system in equilibrium.

3.9 Design Information

3.9.1 Design Method {AASHTO 8.16}

The reinforced concrete sections shall be designed by the load factor design method in accordance with AASHTO 8.16.

3.9.2 Load factors {AASHTO 3.22, Table 3.22.1A}

Table 3.9.2-1 Load Factors				
Col. No.	1	2	3	5
Group	γ	β factors		
		D	L+I	E
X	1.3	1	1.67	β_E

β_E = 1.0 for vertical earth pressure.
β_E = 1.0 for lateral earth pressure for checking (1) positive moments in walls and (2) negative moments in walls, slabs, and floors.
β_E = 0.5 for lateral earth pressure for checking positive moments in slabs and floors.

3.9.3 Flexural Design {AASHTO 8.16.3.2, 8.16.8.3, 8.16.8.4}

Slab and floor thickness required are determined by moment or shear, whichever governs. Preliminary design of thickness based on moment may be determined from using 37.5% of ρ_b ,AASHTO 8.16.3.2, the reinforcement ratio producing a balanced condition. Compression reinforcing is disregarded.

$\rho_b = (0.85\ \beta_1\ f_c' / f_y) \cdot (87000 / (87000 + f_y))$ English {AASHTO Eq. 8-18}

$\rho_b = (0.85\ \beta_1\ f_c' / f_y) \cdot (600 / (600 + f_y))$ Metric

$R_u = \rho\ (fy)\ (1 - ½ \cdot \rho \cdot m)$

$m = fy / (0.85 \cdot (f'c))$

For example, if f'c = 3500 psi (24 MPa) and fy = 60,000 psi (400 MPa), then

β_1	=	0.85	(0.85)
ρ_b	=	0.0249	(0.0251)
37.5% ρ_b	=	0.00935	(0.0094)
m	=	20.17	(920.100)
R_u	=	508.1psi	(3.49 Mpa)
d	=	Unknown	

For singly reinforced rectangular section, d (effective depth in inches or mm) for preliminary design can be calculated as

$$d(\text{in}) = \sqrt{\frac{\text{Mu}(\text{in} - \text{lb})}{\phi * b * \text{Ru}}}$$

For checking the fatigue stresses, AASHTO 8.16.8.3 and the distribution of the flexural reinforcement when fy > 40000 psi (275 Mpa), AASHTO 8.16.8.4, the positive moments in slab and floor are to be computed to include one-half of the end negative moments caused by lateral live load and earth pressure at service load.

The vertical earth pressure on top of culvert shall be reduced to 70% of W at service load.

* For notations in equations shown, see beginning of sec. 8 of AASHTO Standard Specifications for Highway Bridges 1996 Ed.

3.9.4 Minimum Thicknesses

The following minimum thickness shall be used:

Top slab	8 in. (200 mm)
Floor	10 in (250 mm)
Wall	1 in. (25 mm) per ft. (300 mm) of wall height but not less than 9 in. (230 mm)

3.9.5 Critical Sections for Moments {AASHTO 8.8.2}

According to AASHTO 8.8.2, the critical sections for design negative moments in a culvert are:

(1) Case I $S + FV \leq 1.5\ S$ For slab
$W + FH \leq 1.5\ W$ For wall

FH = Fillet Horizontal
FV= Fillet Vertical
W = Wall Thickness
S = Slab Thickness

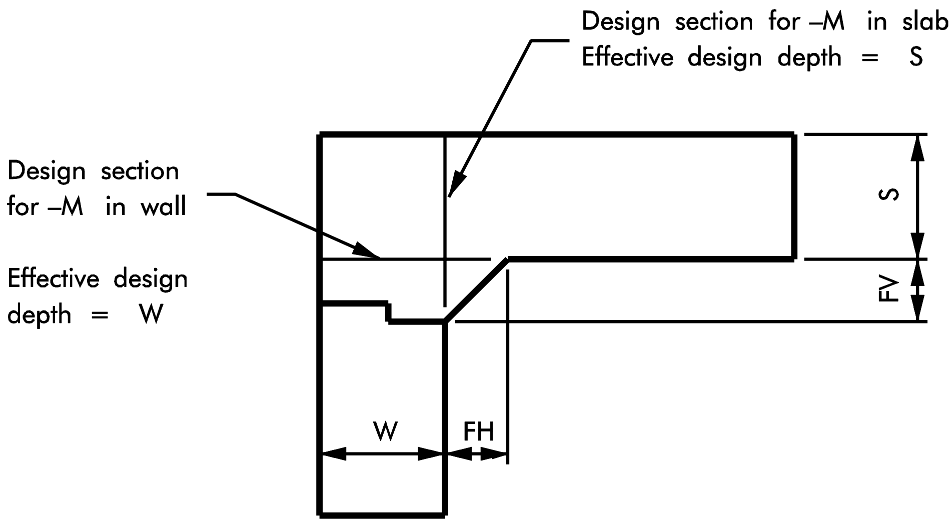


Figure 3.9.5-1
Case I

(2) Case II S + FV > 1.5 S For slab
W + FH > 1.5 W For wall

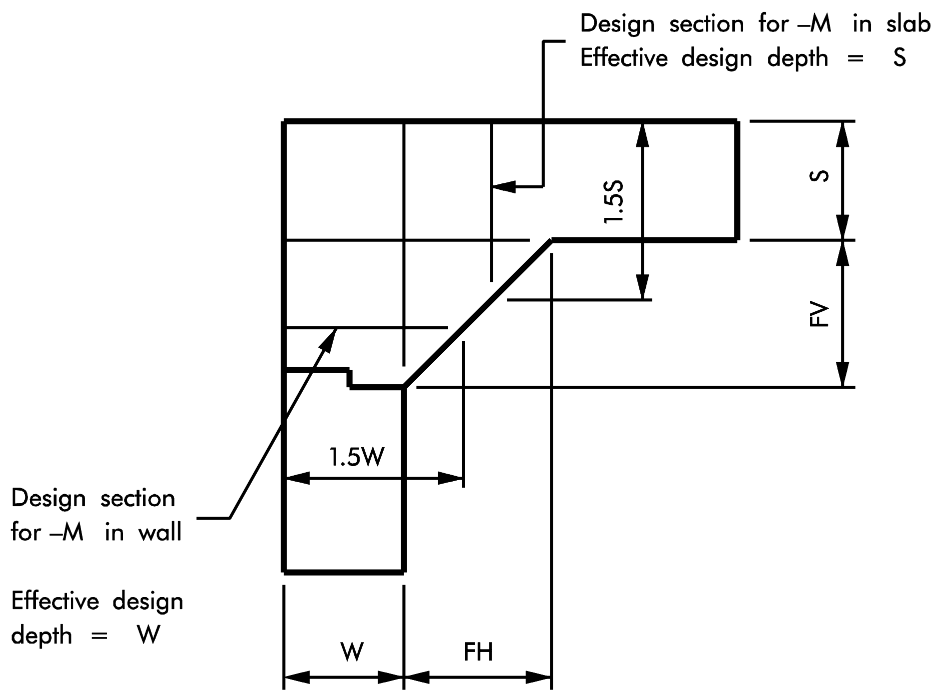


Figure 3.9.5-2
Case II

3.9.6 Critical Shear Sections {AASHTO 8.16.6.1, 8.16.6.2.1}

The critical shear sections in slab and floor are shown below in Figure 3.9.6-1 {AASHTO 8.16.6.1.2}. The permissible shear stress carried by concrete, v_c (psi), shall be computed as follows:

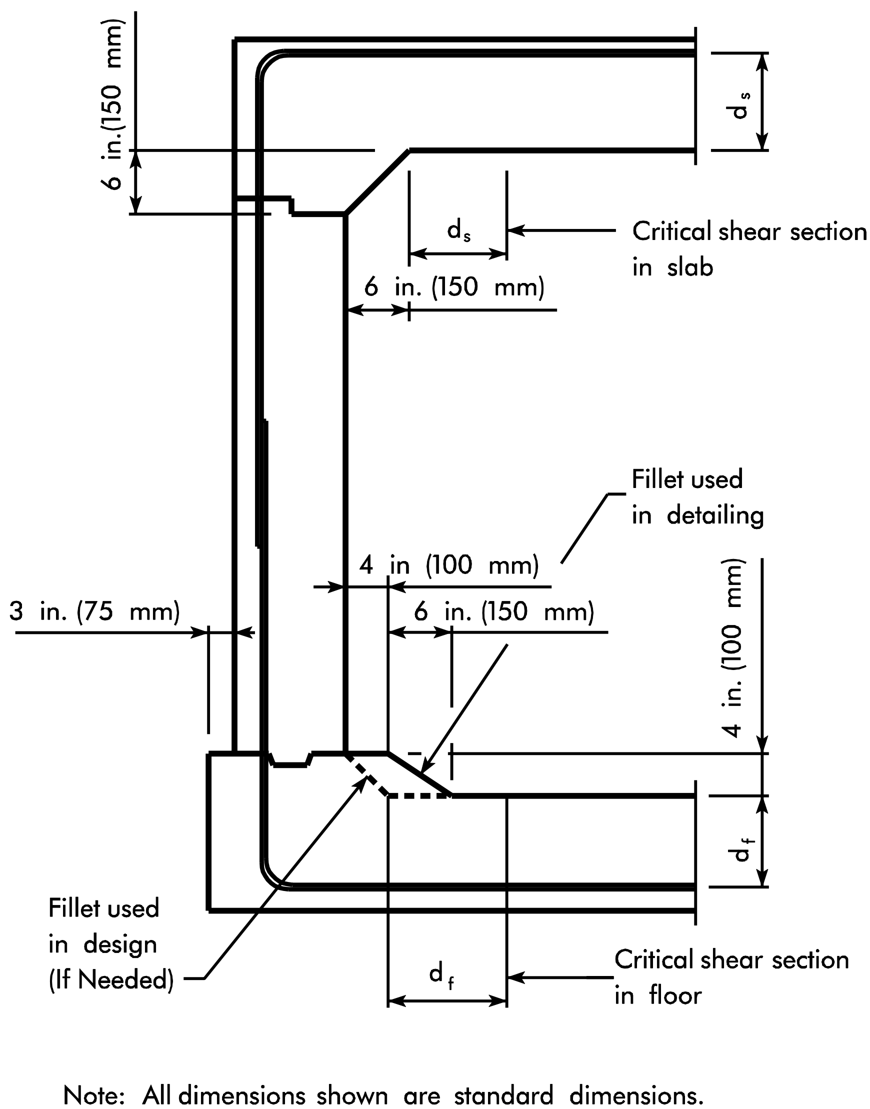


Figure 3.9.6-1
Critical Shear Sections

Note: d_s= design d for slab
d_f = design d for floor

(1) Fill depth < 2 feet AASHTO 8.16.6.2.1

$v_c = 1.9 (f'c)^{1/2} + 2500\, \rho_w (V_u d / M_u)$

Maximum $\nu_c = 3.5 (f'c)^{1/2}$
$V_u d/M_u$ shall not be taken greater than 1.0

(2) Fill depth ≥ 2 feet {AASHTO 8.16.6.7}

$\nu_c = 2.14 (f'c)^{1/2} + 4600 \rho_w (V_u d / M_u)$

Minimum $\nu_c = 3 (f'c)^{1/2}$ (For single cell box culverts only)
Maximum $\nu_c = 4 (f'c)^{1/2}$

$V_u d/M_u$ shall not be taken greater than 1.0

M_u = factored moment occurring simultaneously with V_u at section considered.

For notations shown in the equations, see the variable list {AASHTO Standard Specification for Highway Bridges, 16th ed., Section 8}

3.9.7 Wall Section Design

The wall section shall be designed for the combined effect of direct loads and bending moments. No column action (slenderness effect) is considered.

3.9.8 Crack Control [11/10/93] {AASHTO 17.6.4.7, 18.16.8.4}

AASHTO Standard Specification for Highway Bridges, Article 17.6.4.7 specifies the maximum service load stress in the reinforcing steel for crack control shall be:

$fs = 155 \text{ kip/in} / \beta[(dc) * (A)]^{1/3} \leq 0.6*f_y$ ksi

$fs = 37200 \text{ N/mm} / \beta[(dc) * (A)]^{1/3} \leq 0.6*f_y$ (Mpa)

$\beta = 1 + (d_c / 0.7*d)$

This design requirement for crack control is considered too severe for general application in Iowa. The serviceability specification is intended to provide corrosion protection for structures in actively corrosive soils, which are not prevalent in Iowa. Therefore use:

1. AASHTO Article 8.16.8.4, z = 170 k/in (29.8 MN/m), for crack control for normal situations.
2. In situations where there is zero fill and traffic is directly on the slab use Z=130 kips/in (22.8 MN/m) for members in severe exposure conditions {AASHTO 8.16.8.4}.
3. Culverts subject to corrosive soil or groundwater shall be designed in accordance with {Article 17.6.4.7}.

4.0 Detailing General

When detailing culverts the fill height shall be designed to the nearest 1 ft. (Rounded to the nearest 10 mm for metric designs) and shown in the plan notes and under the longitudinal section on the culvert layout sheet. Profile grades shall be provided on the TS&L sheets so that designers can check the new culvert lengths or culvert extension lengths.

Culverts should be designed based on a single fill height except when stabilization berms are used. In these situations, the designer should check with the section leader to determine if multiple fill heights are necessary for the design.

Culvert lengths shown on plans are to the nearest 1-foot. For Metric projects calculate the length in millimeters and round to the nearest 10 mm.

4.0.1 English Plan Preparation for New Culverts

When preparing plans for new culverts the following guidelines should be used.

Case 1.
New Culvert – Standard size, All Skews, Standard Fill height.
Develop Front Sheet with additional culvert notes not listed on appropriate RCB-G1 sheet.
Refer to Culvert Standards for Barrel and Headwall details or detail appropriate inlet as specified on plans.

Case 2.
New Culvert – Standard size and Non-Standard Fill height.
Develop Front Sheet with culvert notes.
Modify the appropriate Culvert Standard barrel deleting all data and details that do not apply for the project and include in plans.
Refer to Culvert Standards for Headwall details or detail appropriate inlet as specified on plans.

Case 3.
New Culvert – Non-Standard size.
Develop Front Sheet with culvert notes
Modify the appropriate Culvert Standard barrel deleting all data and details that do not apply for the project and include in plans.
Modify Culvert Standards for Headwall details and include in plans or detail appropriate inlet as specified on plans.

4.0.2 English Plan Preparation for Extensions

When preparing plans for culvert extensions, for English plans the following guidelines should be used.

Case 1.

Culvert Extension – Standard size, 0° Skew, Standard Fill height.
Use Standard Sheet 1043 for Front Sheet.
Refer to Culvert Standards for Barrel and Headwall details or detail appropriate inlet as specified on plans.

Case 2.

Culvert Extension – Standard size, 0° Skew, Non-Standard Fill height.
Use Standard Sheet 1043 for Front Sheet.
If additional barrels are required modify the appropriate Culvert Standard barrel deleting all data and details that do not apply for the project and include in plans if applicable.
Refer to Culvert Standards for Headwall details or detail appropriate inlet as specified on plans.

Case 3.

Culvert Extension – Non -Standard size, 0° Skew.
Use Standard Sheet 1043 for Front Sheet.
If additional barrels are required modify the appropriate Culvert Standard barrel deleting all data and details that do not apply for the project and include in plans.
Modify Culvert Standards for Headwall details and include in plans or detail appropriate inlet as specified on plans.

Case 4.

Culvert Extension – Standard size, Skewed, Standard Fill height.
Use Standard Sheet 1043 for Front Sheet.
Use Standard Sheet 1044 for detailing existing culvert junction section.
Refer to Culvert Standards for remaining Barrel details if applicable.
Refer to Culvert Standards for Headwall details or detail appropriate inlet as specified on plans.

Case 5.

Culvert Extension – Standard size, Skewed, Non-Standard Fill height.
Use Standard Sheet 1043 for Front Sheet
Use Standard Sheet 1044 for detailing existing culvert junction section
If additional barrels are required modify the appropriate Culvert Standard barrel deleting all data and details that do not apply for the project and include in plans if applicable.
Refer to Culvert Standards for Headwall details or detail appropriate inlet as specified on plans.

Case 6.

Culvert Extension – Non -Standard size, Skewed.
Use Standard Sheet 1043 for Front Sheet
Use Standard Sheet 1044 for detailing existing culvert junction section
If additional barrels are required modify the appropriate Culvert Standard barrel deleting all data and details that do not apply for the project and include in plans if applicable.
Modify Culvert Standards for Headwall details and include in plans or detail appropriate inlet as specified on plans.

4.0.3 Metric Plan Preparation for New Culverts

When preparing plans for new metric culverts the following guidelines should be used.

Case 1.
New Culvert – Standard size, All Skews, Standard Fill height.
Develop Front Sheet with additional culvert notes not listed on appropriate MRCB-G1 sheet.
Refer to Culvert Standards for Barrel and Headwall details or detail appropriate inlet as specified on plans.

Case 2.

New Culvert – Standard size and Non-Standard Fill height.
Develop Front Sheet with culvert notes.
Use Standard Sheet M1055 for Barrel Details
Refer to Culvert Standards for Headwall details or detail appropriate inlet as specified on plans.

Case 3.
New Culvert – Non-Standard size.
Develop Front Sheet with culvert notes
Use Standard Sheet M1055 for Barrel Details
Modify Culvert Standards for Headwall details and include in plans or detail appropriate inlet as specified on plans.

4.0.4 Metric Plan Preparation for Extensions

When preparing plans for metric culvert extensions, ~~for Metric plans~~ the following guidelines should be used.

Case 1.
Culvert Extension – Standard size, 0° Skew, Standard Fill height.
Use Standard Sheet M1043 for Front Sheet
Refer to Culvert Standards for Barrel and Headwall details or detail appropriate inlet as specified on plans.

Case 2.
Culvert Extension – Standard size, 0° Skew, Non-Standard Fill height.
Use Standard Sheet M1043 for Front Sheet.
Use Standard Sheet M1055 for Barrel Details.
Refer to Culvert Standards for Headwall details or detail appropriate inlet as specified on plans.

Case 3.
Culvert Extension – Non -Standard size, 0° Skew.
Use Standard Sheet M1043 for Front Sheet
Use Standard Sheet M1055 for Barrel Details.
Modify Culvert Standards for Headwall details and include in plans or detail appropriate inlet as specified on plans.

Case 4.
Culvert Extension – Standard size, Skewed, Standard Fill height.
Use Standard Sheet M1043 for Front Sheet.
Use Standard Sheet M1044 for detailing existing culvert junction section.
If additional barrels are required refer to Culvert Standards for remaining Barrel details.
Refer to Culvert Standards for Headwall details or detail appropriate inlet as specified on plans.

Case 5.
Culvert Extension – Standard size, Skewed, Non-Standard Fill height.
Use Standard Sheet M1043 for Front Sheet.
Use Standard Sheet M1044 for detailing existing culvert junction section.
If additional barrels are required use Standard Sheet M1055 for Barrel Details.
Refer to Culvert Standards for Headwall details or detail appropriate inlet as specified on plans.

Case 6.
Culvert Extension – Non -Standard size, Skewed.
Use Standard Sheet M1043 for Front Sheet
Use Standard Sheet M1044 for detailing existing culvert junction section.
If additional barrels are required use Standard Sheet M1055 for Barrel Details.

Modify Culvert Standards for Headwall details and include in plans or detail appropriate inlet as specified on plans.

4.1 Guidelines for Conversion of Program Output to Metric Plans

When converting the output from the Mainframe programs SIGLBOX and MULTBOX to metric plans, the following guidelines should be used. Calculate the fill height in millimeters and then convert to the nearest whole foot rounding up for 0.5 and greater and rounding down for less than 0.5.
Run SIGLBOX or MULTBOX program. Use the data and convert to metric (i.e. concrete thicknesses and reinforcing bar conversion). The design fill listed on the plans shall be the program fill (feet) converted to the nearest 10 millimeters.

4.1.1 Bar Lengths

Reinforcing bar lengths are to be rounded to 10 mm increments. Round up to the nearest 10 mm when reinforcing bar cover is not a problem and down to the nearest 10 mm to maintain the minimum required reinforcing bar cover. Reinforcing bars that run the full length or width of the culvert will need to have their lengths recalculated because of the change in the length and width of the culvert due to metric conversion.

4.1.2 Bar Sizes

When using the culvert programs for a nonstandard culvert on a metric project, use a #10 bar for all longitudinal distribution bars that are shown as #4 bars on the culvert program output (b, e and f bar designations). Any other #4 bars shown (a, k and m bar designations) in the output shall use #15 metric bars as a substitute. Spacing for all reinforcing steel shall be converted as shown in article 4.1.7.

4.1.3 Spans and Heights

Spans and heights shall be converted to 300 mm increments as shown in Table 4.1.3-1.

Table 4.1.3-1 - Span and Clear Height

Computer Output (ft)	Metric Conversion (mm)	Round to (mm)
3	914.4	900
4	1219.2	1200
5	1524	1500
6	1828.8	1800
8	2438.4	2400
10	3048	3000
12	3657.6	3600

4.1.4 Fill Heights

Fill heights shall be converted as shown in Table 4.1.4-1.

Table 4.1.4-1 - Fill Heights

Computer Output (ft)	Metric Conversion (mm)	Round to (mm)
0	0	0
1	304.8	300
2	609.6	610
3	914.4	910
4	1219.2	1220
5	1524	1520
6	1828.8	1830
7	2133.6	2130
8	2438.4	2440
9	2743.2	2740
10	3048.0	3050
11	3352.8	3350
12	3657.6	3660
13	3962.4	3960
14	4267.2	4270
15	4572	4570
16	4876.8	4880
17	5181.6	5180
18	5486.4	5490
19	5791.2	5790
20	6096.0	6100
21	6400.8	6400
22	6705.6	6710
23	7010.4	7010
24	7315.2	7320
25	7620.0	7620

4.1.5 Reinforcing Cover

Reinforcing cover shall be rounded to the nearest 10 mm as shown in Table 4.1.5-1.

Table 4.1.5-1 - Rebar Cover

Computer Output (in)	Metric Conversion (mm)	Round to (mm)
1.5	38.1	40
2.0	50.8	50
2.25	57.2	60
3.0	76.2	80
3.5	88.9	90
4.25	108.0	110

4.1.6 Slab, Floor, and Wall Thickness

For slab, floor and wall thicknesses round up to the nearest 5 mm except in situations where the value is less then one mm then round down ~~as shown in Table 4.1.6-1.~~. For wall thicknesses round down to the nearest 5 mm to allow for standard form ties to be used, which are usually available in ½ inch increments without increasing the wall thickness too much. See Table 4.1.6-1.

Table 4.1.6-1 – Slab, Floor, and Wall Thickness

Computer Output (in)	Metric Conversion (mm)	Round Slab and Floor Thickness to (mm)	Round Wall Thickness to (mm)
8.0	203.2	205	200
8.5	215.9	215	215
9.0	228.6	230	225
9.5	241.3	245	240
10	254	255	250
10.5	266.7	270	265
11	279.4	280	275
11.5	292.1	295	290
12	304.8	305	300
12.5	317.5	320	315
13	330.2	330	330
13.5	342.9	345	340
14	355.6	355	355
14.5	368.3	370	365
15	381	385	380
15.5	393.7	395	390
16	406.4	410	405
16.5	419.1	420	415
17	431.8	435	430
17.5	444.5	445	440
18	457.2	460	455
18.5	469.7	470	465
19.0	482.6	485	480
19.5	495.3	495	495
20.0	508	510	505
24.5	622.3	625	620
26	660.4	660	660
27	685.8	685	685
28	711.2	715	710

4.1.7 Bar Spacing

The transverse and vertical reinforcing bar spacing is to be converted to metric by using the values shown in Table 4.1.7-1. The maximum spacing of reinforcing bars is to be 450 mm (1.4764 ft.).

Table 4.1.7-1 – Transverse and Vertical Bar Spacing

Computer Output (in)	Metric Conversion (mm)	Round to (mm)
4.5	114.3	115~~110~~
6	152.4	150
7.5	190.5	190
9	228.6	220
11	279.4	270
12	304.8	300
15	381	380
16	406.4	400
18	457.2	450

4.1.8 Bar Designation

For metric plans the reinforcing bar size will be removed from the reinforcing bar designation. For example 7k1 will become k1.

4.1.9 Keyways

Keyways that are provided at construction joints shall use a bevel of approximately 10 degrees. See Figure 4.1.9 for an example using the 10 degrees bevel.

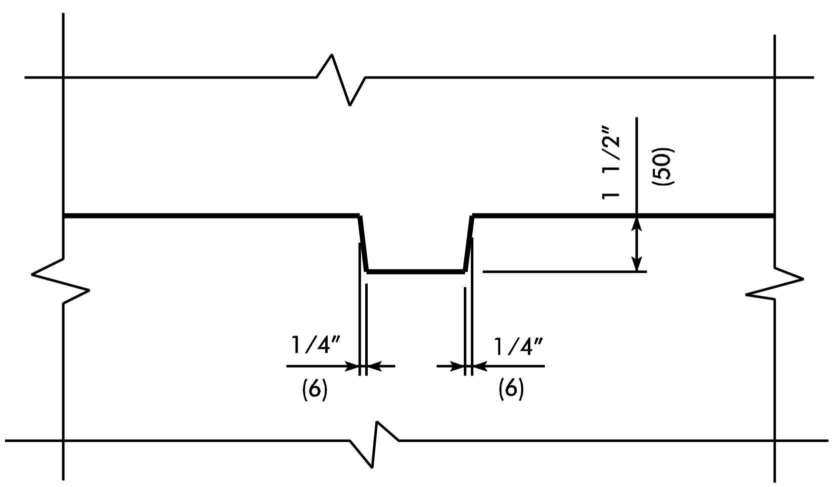


Figure 4.1.9
Example Keyway Detail

4.1.10 Barrel Length

For culverts run on the mainframe programs to be used in metric projects use 38 ft for the culvert length.

4.2 Culverts with 0 fill

When detailing culverts with a 0 fill height, paving notches for approach slabs shall be provided. In addition, the reinforcing steel in the slab and paving notch shall be epoxy coated. Adjustments in the reinforcing steel development length and lap lengths shall be made for the epoxy coated bars. The slab depth and top corner bar shall be adjusted to take into account the roadway crown. The length of the top corner bar should be based on providing a lap for the thickest slab section. The bottom corner bar should be a constant length. Construction joints in the roadway area shall be avoided. See Figure 4.2-1 for details. Clear cover for the top reinforcing steel shall be 2 ½ inches (65 mm).

Epoxy coated bars shall be increased by the following lengths for the sizes shown in Table 4.2-1 and 4.2-2 :

Table 4.2-1
Epoxy Coated Bars (English)

Bar Size	Increased Bar Length (in)
4	11
5	14
6	17
7	22
8	29

Table 4.2-2
Epoxy Coated Bars (Metric)

Bar Size	Increased Bar Length (mm)
15	240
20	300
25	500

Length increases were based on a Class B splice, other bar, and less than 6 in. spacing.

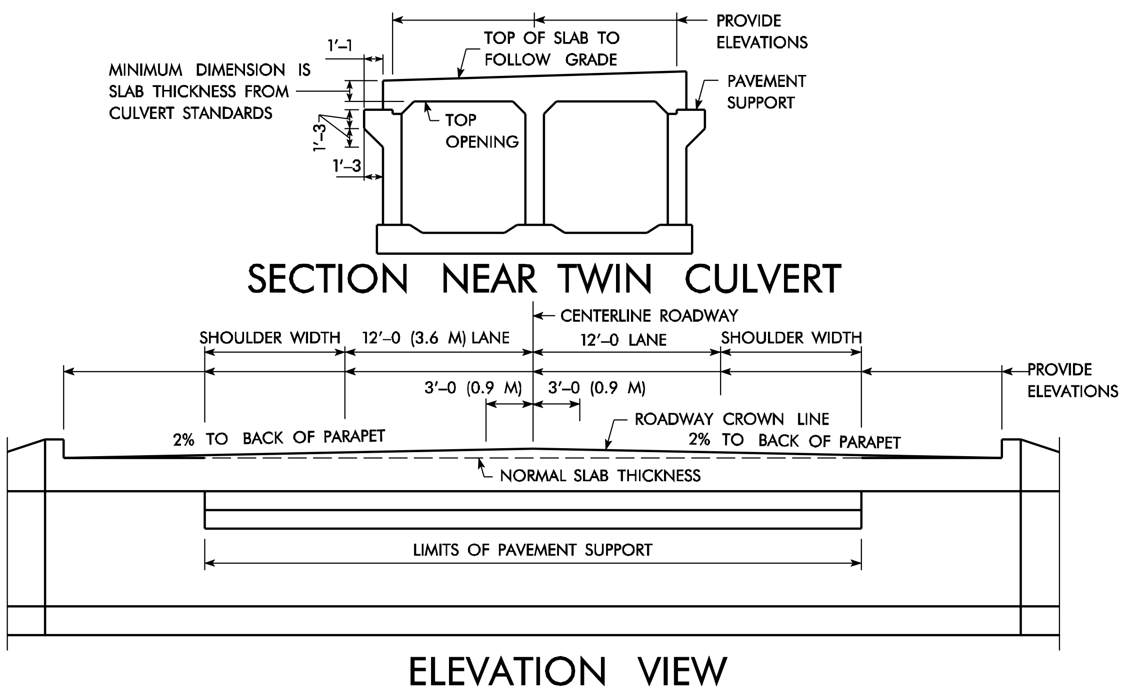


Figure 4.2-1
Details Culvert with 0 Fill

4.3 Reinforcing

4.3.1 Maximum Spacing {AASHTO 8.20, 8.21.6}

In slabs, floors, and walls, reinforcing shall be spaced a maximum of 1.5 times the section thickness or 18 inches (450 mm).

4.3.2 Minimum Spacing {AASHTO 8.21}

In slabs, floors, and walls, the minimum reinforcing spacing shall be 4.5 inches (115 mm): however, in situations where the reinforcing is placed radially such as bent barrels, 3 inches (75 mm) may be used. See article 4.7.2 "Detailing of Transverse Bars at Bends" for additional details.

4.3.3 Distribution of Reinforcing for Fill Depths < 2 feet (600 mm) {AASHTO 3.24.10}

When the depth of fill is 2 feet (600 mm) or less, distribution steel shall be provided in the bottom of the top slab. The amount is computed as a percentage of the required positive moment reinforcing steel as calculated by the following formula in AASHTO 3.24.10.

*Percentage = $100/ (S)^{1/2}$ Where S is the clear span length in ft.
*Percentage = $1750/ (S)^{1/2}$ Where S is the clear span length in mm.

*Maximum percentage is equal to 50%.

Maximum spacing of distribution steel shall not exceed 18 in (450 mm).

4.3.4 Minimum Area of Reinforcing {AASHTO 8.20}

For surface of slab and walls not otherwise reinforced, a minimum area of reinforcement equivalent to at least 1/8 in^2 / ft. (80 mm^2 / 300 mm). shall be provided. The minimum size of this reinforcement shall be no. 4 (no.15) and spaced not farther apart than 3 times the slab or wall thickness or 18 inches (450 mm).

4.3.5 Minimum Clear Cover

Minimum clear cover distance over main reinforcing steel shall be as shown in Table 4.3.5-1.

Table 4.3.5-1 Minimum Clear Cover

Location	Clear Cover
Slab top and bottom	2.00 in. (50 mm)
Wall (both surfaces)	2.00 in. (50 mm)
Top of floor	2.25 in. (60 mm)
*Bottom of floor	3.50 in. (90 mm)

End clearance of the vertical bars is 2 inches at the top and 3 inches at the bottom or 3.5 inches at the bottom if the overall culvert height is not to the whole inch .

End clearance of the vertical bars is 50 mm at the top and 90 mm at the bottom or 75 mm at the bottom if the overall culvert height is not to the whole inch 25 mm.

* The bottom 2 inches (50 mm) of concrete (mud mat) shall not be considered effective in the design of floor section.

4.3.6 Culvert Reinforcing Bar Symbols [5/17/78]

In culvert plans the use of uniform symbols for reinforcing bars makes identification easier for the contractor, fabricator, and the detailer; therefore, use the following symbols as shown in Table 4.3.6-1 for reinforcing steel in the indicated locations in the barrel:

Table 4.3.6-1 Standard Bar Symbols

Location	Designation
Slab transverse	k
Slab longitudinal	e
Wall vertical	a
Wall horizontal	b
Floor transverse	m
Floor longitudinal	f

4.3.7 Single Culvert Modifications for Culvert Extensions [8/9/93]

When the transverse bars and corner bars are being laid along the skew in a single barrel culvert extension use the guidelines shown in Table 4.3.7-1:

Table 4.3.7-1
k Factor for Skewed Extensions

Skew (degrees)	“k”

15	1.035
30	1.155
45	1.414

Multiply "k" times the minimum area of steel required (square inches) found on the computer printout from the SIGLBOX program to determine a new bar size and spacing needed. The revised bar spacing is detailed parallel to the centerline of the culvert.

Note: Care should be used in the detailing with skewed headwall to make sure areas of the floor of the headwall are adequately reinforced.

When determining the new corner bar horizontal and vertical lengths use the following guidelines and Table 4.3.7-2 and 4.3.7-3:

If there is no change in bar size the vertical leg length will not change. The horizontal leg length, given on the "computer print out", should be increased by multiplying it by the secant (1/cosine) of the skew angle.

If there is a bar size change, the horizontal leg length shall be increased by the difference in the development length. The horizontal leg shall have this difference added before skewing the leg and increasing its length by multiplying by the secant (1/cosine) of the skew angle. The vertical leg of the top corner bar should reflect the splice difference. The bottom corner vertical leg length will not change in length.

Table 4.3.7-2 Splice and Development Length (English)

Bar Size	*Splice Lap Length (in.)	∆ Corner Bar Pin Bends (in.)	Ø Development Lengths (inches)	
			< 6 in. Spacing	>= 6 in. Spacing
4	17	3	12	12
5	21	3 ¾	15	12
6	25	4 ½	18	15
7	34	5 ¼	25	20
8	44	6	32	26
9	56	9 ½	41	33

* Based on other bar spacing of 6" or more, Class C splice.
∆ Bend dimension for standard hooks and bends.
Ø Based on tension development length for other bar.

Table 4.3.7-3 Splice and Development Length (metric)

Bar	*Splice Lap	∆ Corner Bar	Ø Development Lengths (mm)

Size	Length (mm)	Pin Bends (mm)	< 150 mm Spacing	>= 150 mm Spacing
10	360	70	310	310
15	510	100	380	310
20	640	120	470	380
25	1060	150	780	620
30	1480	240	1090	870
35	2110	290	1550	1240

* Based on other bar spacing of 150 mm or more, Class C splice.
∆ Bend dimension for standard hooks and bends.
Ø Based on tension development length for other bar.

Skewed extensions for twin and triple culverts shall use the reinforcing spacing from the standard culvert program perpendicular to the centerline of the extension. Bar cutoff details shall be used and shown in the plans for the skewed areas as shown in the metric example on Figure 4.3.7-1. Additional bars shall be provided at the extension connection to reinforce the edge of the bottom of the slab and the top of the floor. The bars shall be spaced at 4.5 inches (120 mm). If situations occur where bars need to be detailed along the skew then approval needs to be given by the section leader.

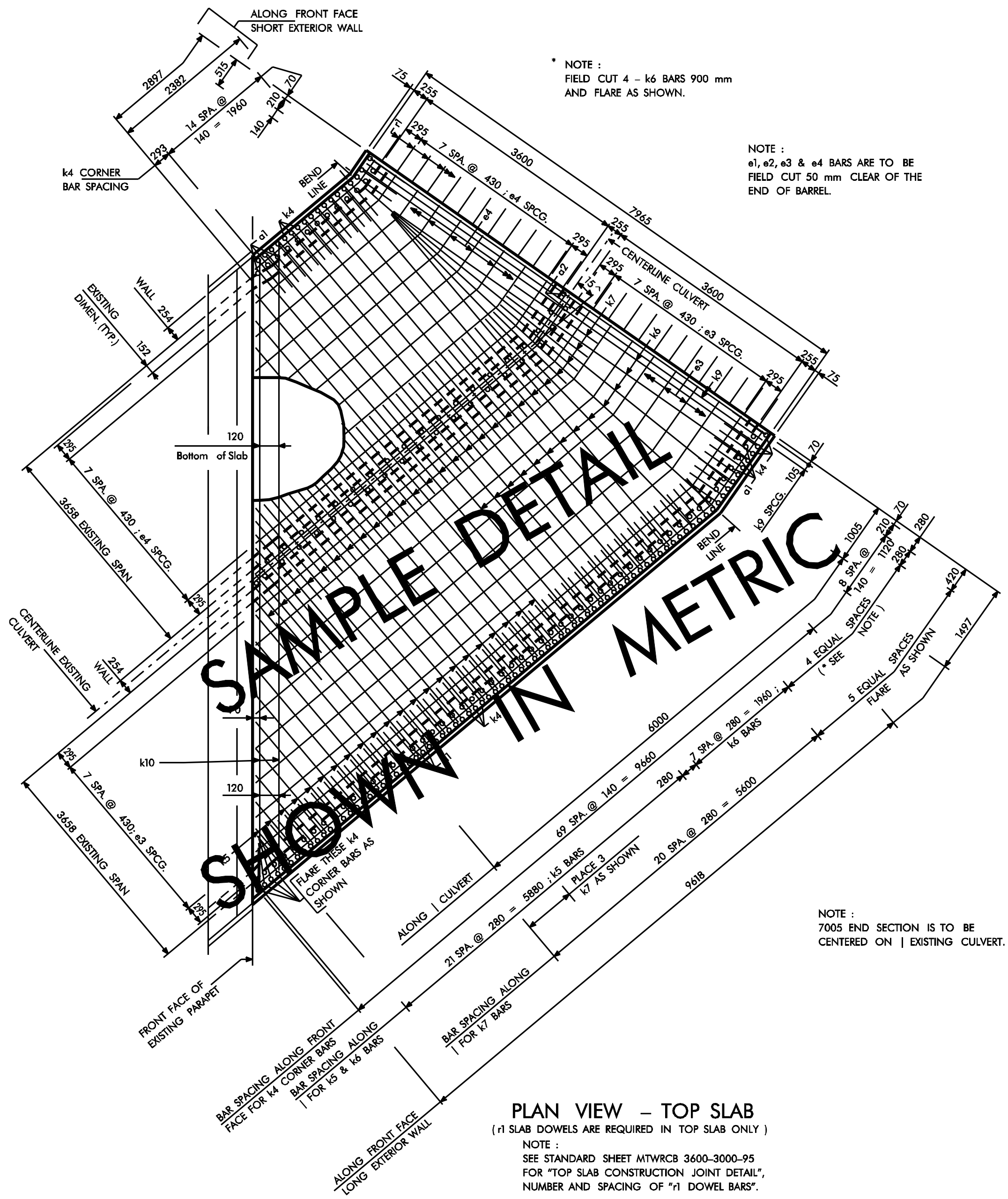


Figure 4.3.7-1
Sample Detail Skewed Extension

4.4 Joint Placement [9/26/97]

4.4.1 English

Whenever practicable, construction joints for intermediate culvert barrel sections should be placed at a maximum of 38 ft. intervals, and be of equal lengths. Note that the current single barrel culvert standards are detailed so that all transverse and vertical reinforcing bar spacing repeat in 3-ft intervals. Culvert lengths should be in increments of 3 ft. with lengths of 38 ft., 35 ft., 32 ft., etc.

4.4.2 Metric

For metric culverts, the construction joints for intermediate culvert barrel sections should be placed at the maximum length of 11480 mm if possible. When shorter sections need to be used, calculate the barrel length to the nearest 100 mm. Repeating barrel lengths should be used as much as possible.

4.4.3 Barrel Joint Locations for Fill Heights of 5 ft and less

If possible locate culvert joints outside of the pavement boundaries when the fill height is 5 ft. (1520 mm) or less. Uneven settlement of barrel joints under the pavement can cause cracking problems in the pavement. The location of the joint becomes even more critical when multiple barrels are used because the wider the culvert the more they tend to settle unevenly at the joint. Fill heights of 6 ft (1830 mm) and greater do not have as much of an effect on the pavement settlement. The higher fills provide better distribution of pavement loads decreasing the chances of uneven settlement.

If the culvert joint is inside the pavement boundaries, make sure that the joint is not at the centerline of roadway. If settlement problems were to develop, then one lane could still be kept open during repairs.

4.4.4 End Barrel Lengths

End barrel sections, next to the headwalls, should, preferably have a minimum length of 10 ft (3000 mm). This minimum length helps with the distribution of settlement and secures the end section into the earth slope. The summation of the lengths of the frost troughs for the headwall and end barrel section should preferably be a maximum of 38 ft (11480 mm). This maximum length is based on the length of the formwork most contractors have available to form the frost troughs.

When working with larger skewed culverts, it may not be possible to keep the length of the end barrel sections within the limits specified above. In this case it is desirable to keep the short wall, measured along inside face, a minimum of 5 ft. (1500 mm) long (from back of parapet to construction joint).

4.5 Settlement and Camber [8/9/93]

Settlement occurs when the soil under the culvert floors compresses. The Soils Section of Road Design usually furnishes the settlement estimates. If an estimate is not included in the project envelope received from Preliminary Bridge, the Soils Section should be contacted.

If the estimated settlement is 6 inches (150 mm) or more, the culvert shall be cambered and bell joints shall be provided (See the Article “4.6 Bell Joints”). Settlement is considered to be zero at the toes of the fill slopes and maximum at the shoulder lines. Therefore the culverts should be cambered accordingly and the flowline elevations shown at each cambered bell joint. The camber shall be ratioed between the maximum settlement at the shoulder line and zero at the flow line inlet and outlet. The anticipated settlement should be noted under the "Longitudinal Section Along Centerline Culvert in the plans. If no measurable settlement exists, the “Anticipated Settlement=Negligible” note should be provided below the “Longitudinal Section Along Centerline Culvert” heading on the situation plan sheet.

4.6 Bell Joints [8/9/93]

4.6.1 Application of Bell Joints

The reasons for providing bell joints are as follows:

1. If settlements of 6 inches (150 mm) or greater occur, in the area where the culvert is constructed, the culvert construction joints tend to open up in the floors and walls. This will allow the fill to erode through these open joints and cause increased settlement.

2. If fill heights of 35 feet (10 500 mm) or more are built on uncompressible soil, or bedrock, settlement may not be a problem, but some subsidence may occur within the fill itself. This subsidence will cause longitudinal forces to develop and pull the construction joints apart.

Therefore, bell joints shall be provided for all culverts where the following conditions occur:

1. Anticipated settlement is 6 inches (150 mm) or greater.

2. Design fill heights are 35 feet (10 500 mm) or more.

3. When estimated settlements are not available from the Soils Section, the bell joints should be used for single culverts with 20 feet (6000 mm) or more of fill and for multiple span culverts with 15 feet (4500 mm) or more of fill.

4. For situations where culvert extensions are being used and the bell joints have been used on the existing culvert then strong consideration should be made to providing bell joints on the extensions as well. See article 8.4 for additional information and details.

If the need for bell joints is questionable, it is best to use them to ensure against possible culvert joint deterioration.

If bell joints are locked into bedrock they will not rotate and function as designed. Therefore, if bedrock is present in the streambed the flowline elevation should be adjusted so that the entire bell joint is above the surface of the rock or the rock must be excavated and backfilled with suitable material. Generally bell joints would not be used in this situation. Any decision made should be verified with the Soils Section.

4.6.2 Detailing of Bell Joints

Longitudinal reinforcing is not allowed to extend through the bell joints.

The "m1" floor bars, in the area of the bell joints, must be shortened on the design plan or by field cutting, to prevent them from locking up the bell joint.

Details similar to the Figure 4.6.2-1 should be shown on the plans showing the correct orientation of the bell joint with flow. In addition, bell joint details are provided in the standards. The barrel bell joints allow permissible construction joints to simplify construction.

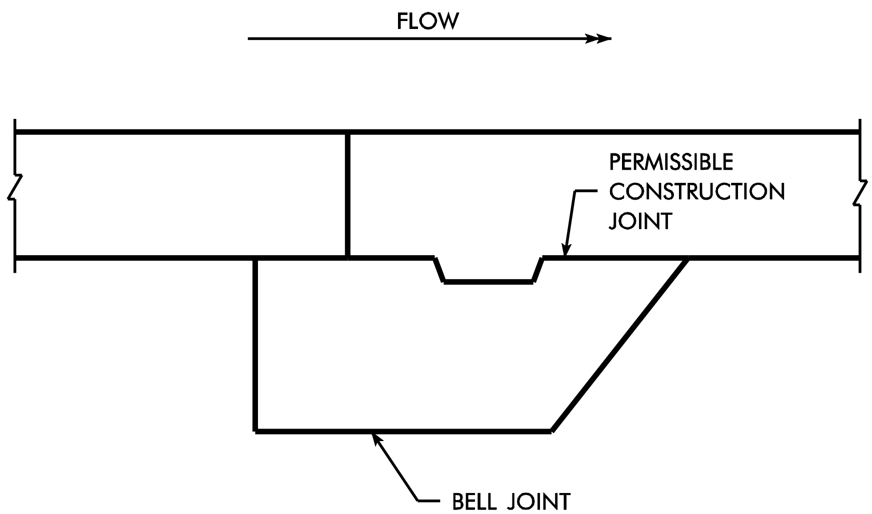


Figure 4.6.2-1
Typical Barrel Bell Joint

If the slab, wall or floor thickness changes from what is shown on the bell joint standard, the standard shall be modified. The changes in the standard shall reflect the new slab, wall and floor thickness and concrete quantities adjusted accordingly. The bill of reinforcing steel will be modified to reflect the corrected bar lengths and weight (mass). The title block will be replaced with the one used for the design and the modified bell joint sheet included as a design sheet in the plans.

When the culvert is designed for varying fill heights the bell joint details must address the change in floor and slab thickness. The thickness of the designed culvert section shall not be reduced.

4.6.2.1 Barrel Bell Joint Modification

When the slab, wall or floor thickness changes from what is shown on the Bell Joint Standard, the bell joint sheet will be modified and included in the plans. The bell joint sheet will reflect the correct slab, wall and floor thickness and concrete quantities adjusted accordingly. The bill of reinforcing steel will be modified to reflect the correct bar lengths and weight (mass). The Bent Bar Details will be modified also. All information of other sizes should be deleted on this sheet. The title block for the specific design will be used in place of the block shown on the standard sheet.

When the RCB is designed for varying fill heights the bell joints must address the change in floor and slab thickness. See Figure 4.6.2-1 for details.

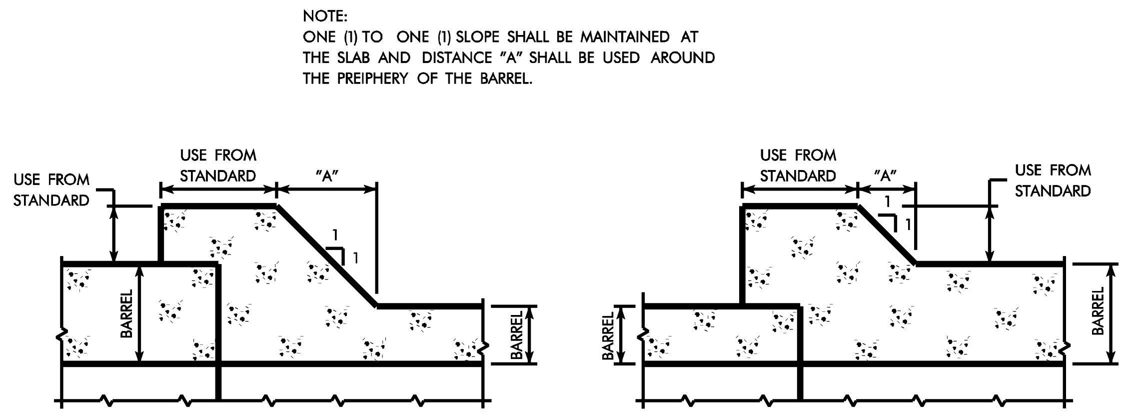


Figure 4.6.2-2
Barrel Bell Joint Adjustments

4.7 Curved Box Culverts

4.7.1 General

Culvert contractors have requested that curved box culverts be built in short straight segments rather than curves.

The AASHTO Highway Drainage Guidelines Handbook indicates that short segments bent at a maximum of 15 degrees have flow characteristics that are comparable to those of a curve.

Therefore, curved culverts that are long enough and have a radius of curvature gentle enough are currently being built in short segments. 38 feet (11 480 mm) is used as the maximum barrel section length, along centerline, and 15 degrees is used as the preferred bend angle. Bends greater than 15 degrees are allowed with approval of the Preliminary Bridges and Structures Engineer. Also to make detailing and construction easier the distance between the bend locations and the joint locations should be symmetrical for each barrel section. See Figure 4.7.1-1.

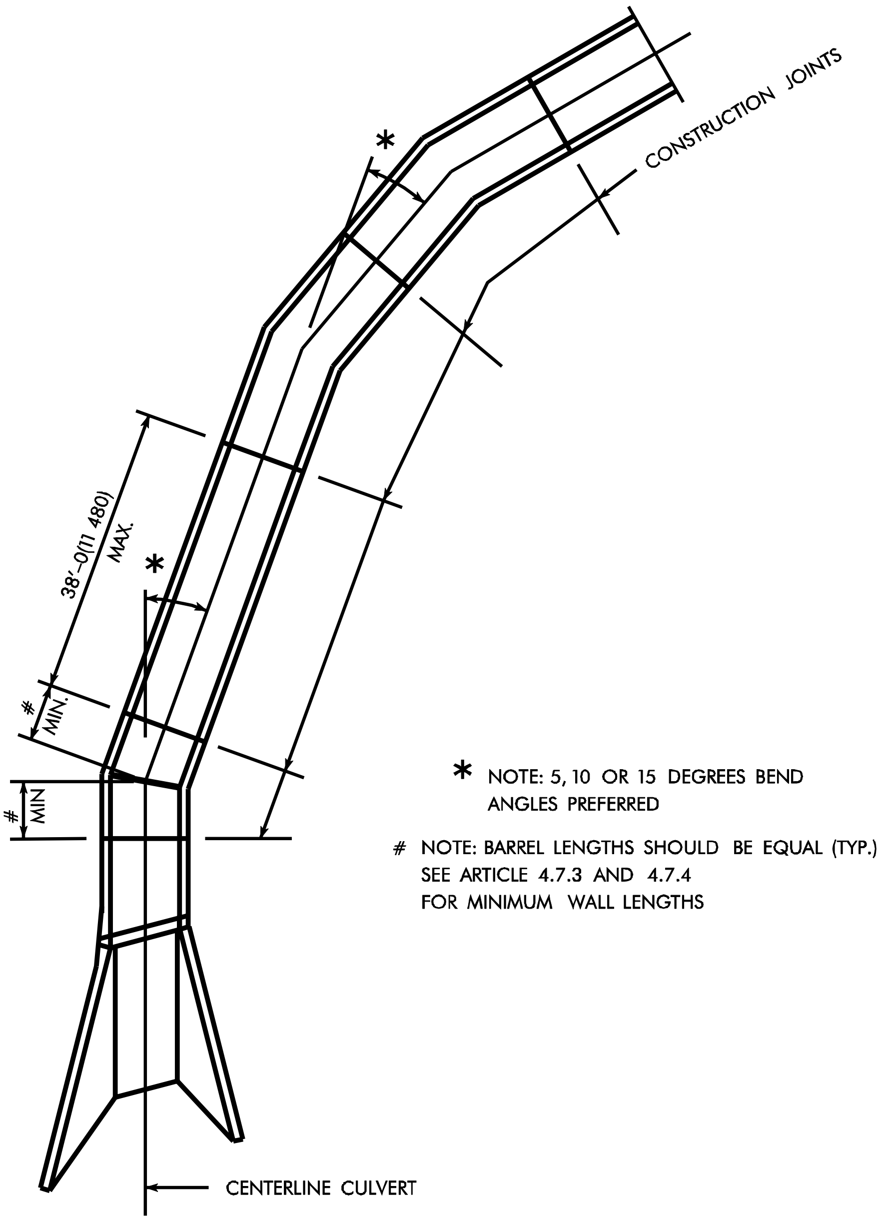


Figure 4.7.1-1
Typical Bent Barrel Layout

4.7.2 Detailing of Transverse Bars at Bends

To help standardize the detailing of bends in reinforced concrete box culvert the following office guidelines should be followed. In addition, details for reinforcing layouts are shown for transverse bars in multiple culverts. See details in Figure 4.7.2-1 through Figure 4.7.2-4. The details were developed to cut down on the number of variable bars and should be used in detailing of the bent barrel sections for single and multiple barrels.

1. Whenever possible try to keep the reinforcing pattern (bar spacing and length) through the bend. Bar spacing should be a minimum of three inches center to center of the bars and a maximum of 1½ times the design bar spacing.
2. When the pattern cannot be kept, drop the pattern and run the reinforcing steel lengths as long as possible following the guidelines described in No. 1 above for minimum and maximum spacing.
3. You may have to draw a plan view of each section to scale and try different layouts to decide which way would be best.
4. At maximum bending moment locations (such as midspan for positive bending and over interior wall for negative bending) the spacing of the reinforcing steel shall not exceed the spacing required by the culvert program (SIGLBOX and MULTBOX).

When detailing the reinforcing try to keep the number of bars used to a minimum and the reinforcing layout as simple as possible for ease of construction.

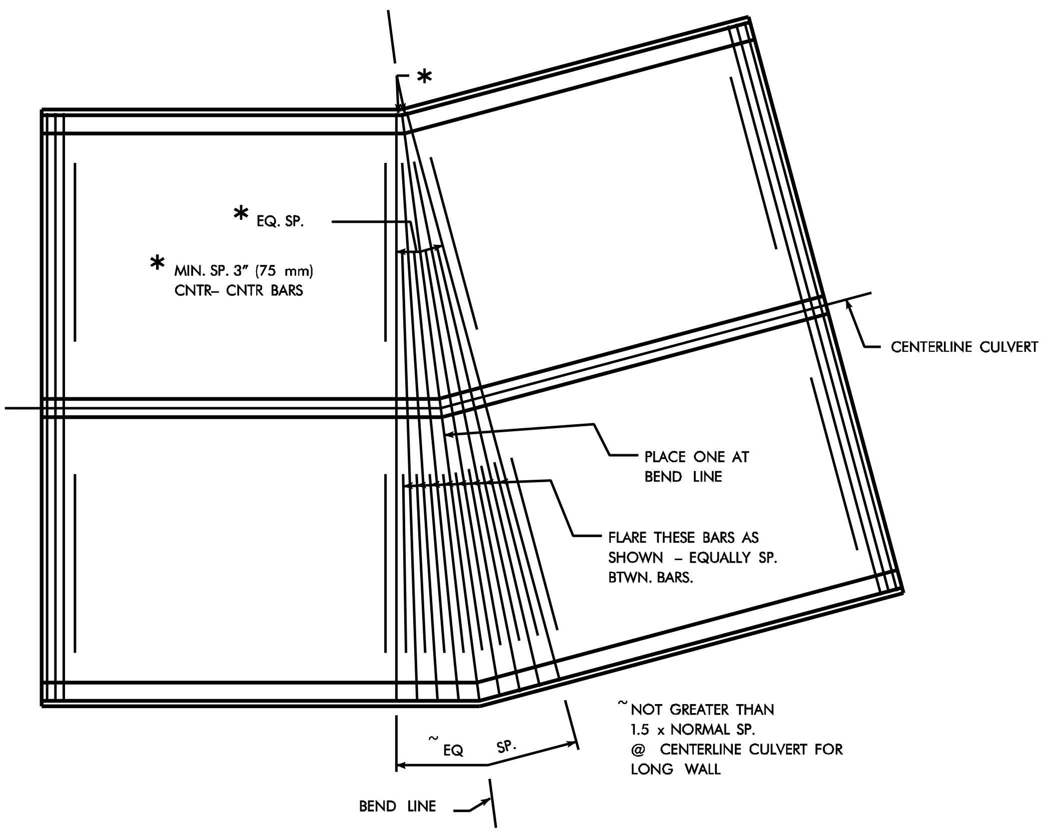


Figure 4.7.2-1
Transverse Reinforcing Layout for
Top of Floor – Plan View

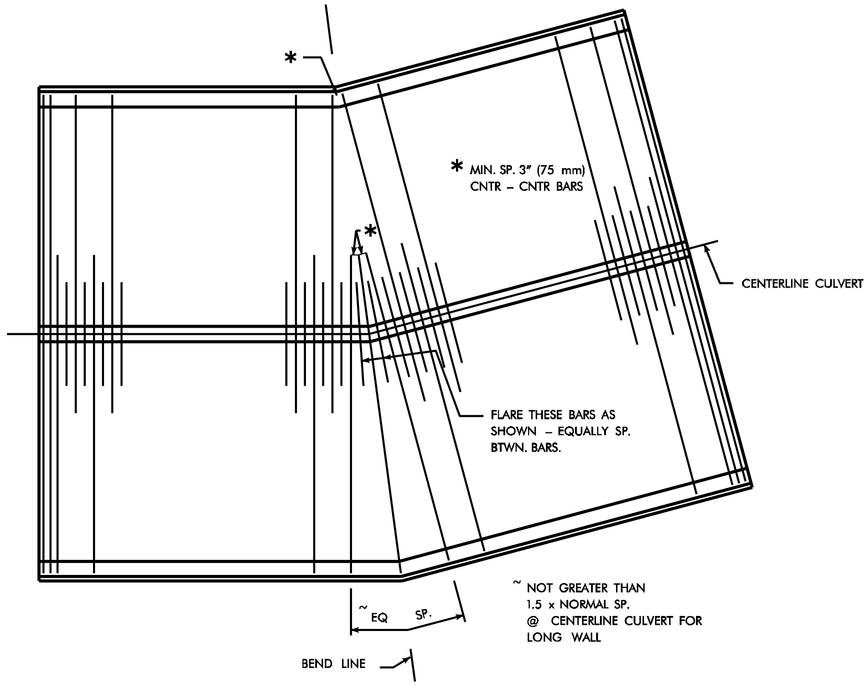


Figure 4.7.2-2
Transverse Reinforcing Layout for
Top of Slab – Plan View

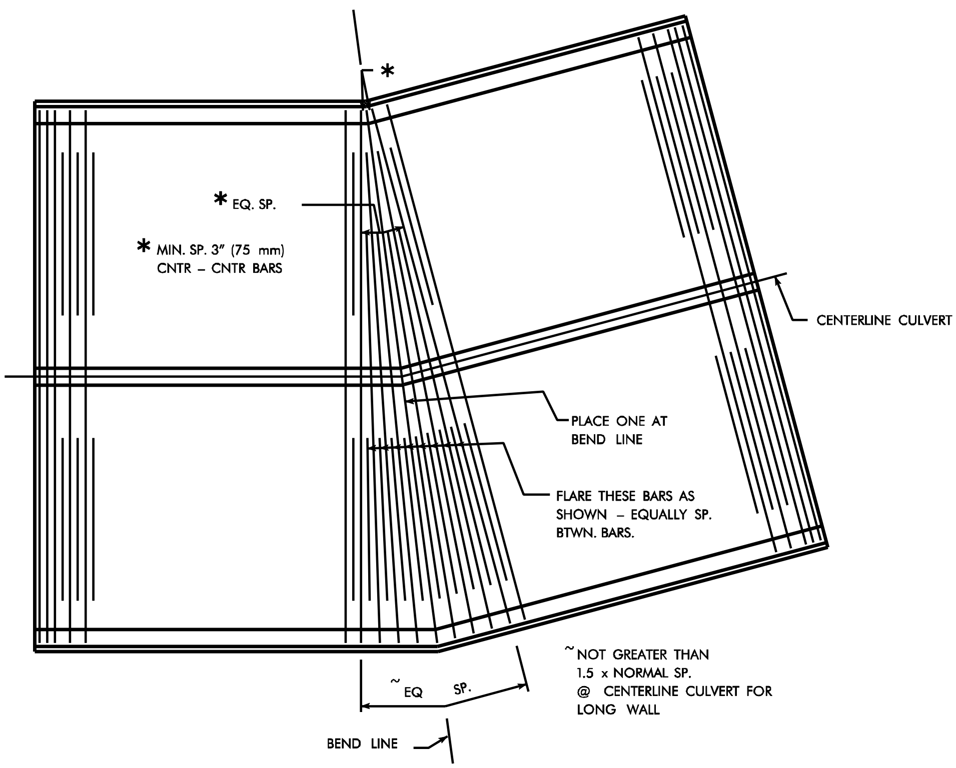


Figure 4.7.2-3
Transverse Reinforcing Layout for
Bottom of Slab – Plan View

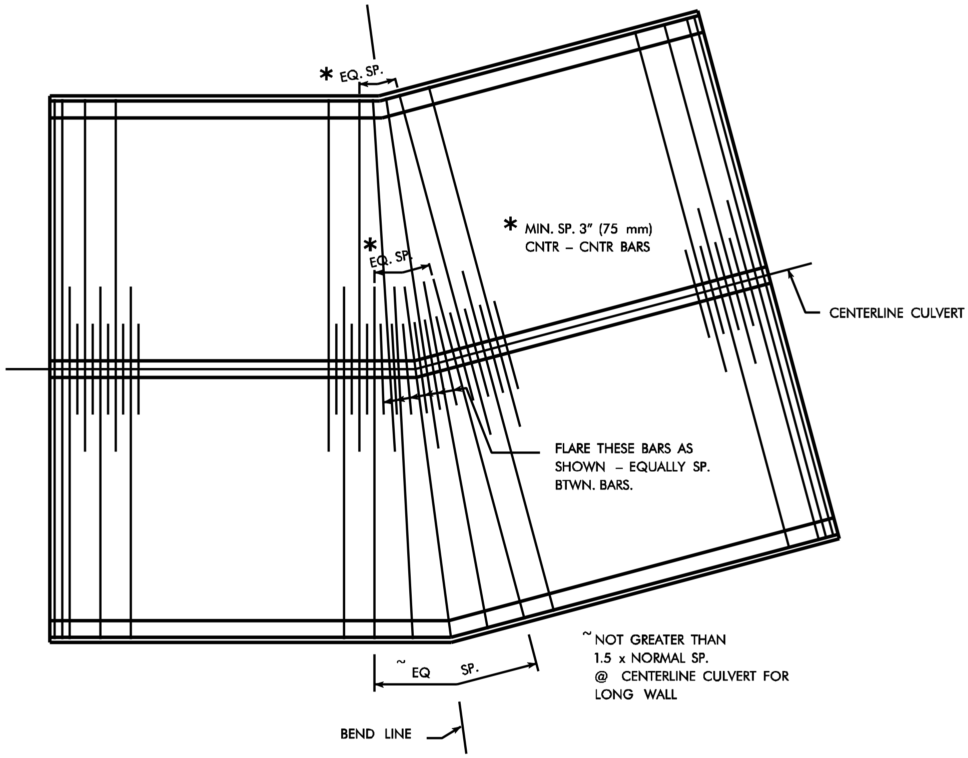


Figure 4.7.2-4
Transverse Reinforcing Layout for
Bottom of Floor – Plan View

4.7.3 Longitudinal Bar Bend Details for Single Barrels

When detailing longitudinal bars for barrel bends, follow the details shown in Figure 4.7.3-1 and 4.7.3-2. Transverse bars shall be flared around the bends as shown in article 4.7.2.

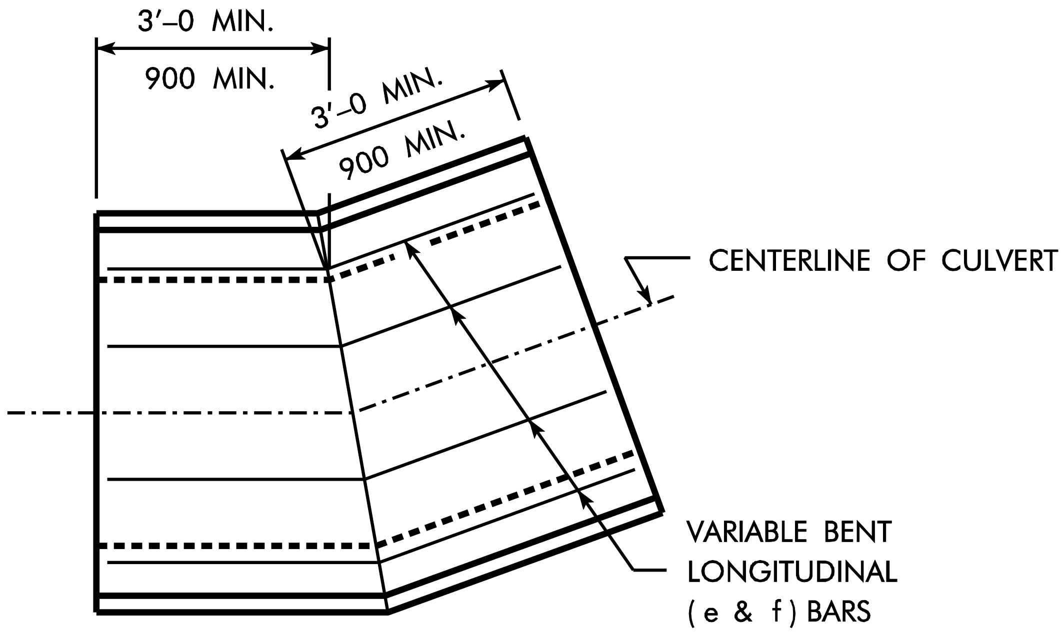


Figure 4.7.3-1
Longitudinal Bar Bends for
4 ft. (1200 mm) to 6 ft. (1800 mm) Span

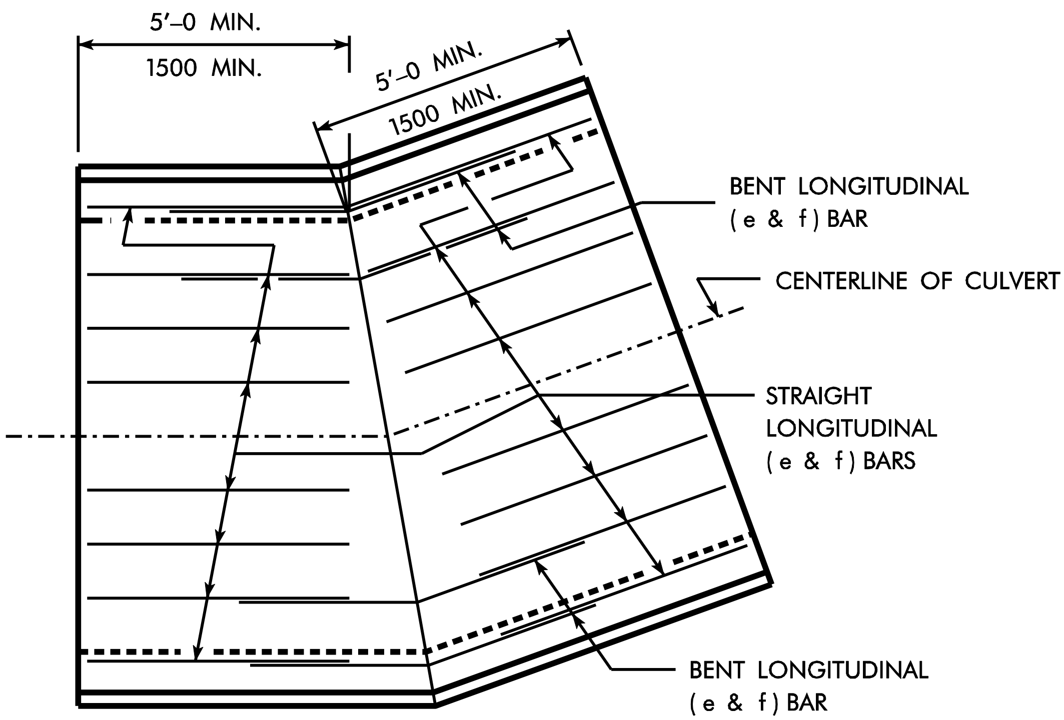


Figure 4.7.3-2
Longitudinal Bar Bends for
8 ft. (2400 mm) to 12 ft. (3600 mm) Span

4.7.4 Longitudinal Bar Bend Details for Multiple Barrel Culverts

When detailing barrel bends, follow the guidelines provided in this section and the details shown in Figure 4.7.4-1 and 4.7.4-2.

4.7.4.1 Reinforcing Bar Lengths

The barrel wall horizontal (b) bars are not to be spliced with a bent bar but made up of a single bent bar. The bar lengths are determined using the centerline wall length of each wall for the bars placed in both faces. The horizontal bars in each wall will have a different length and bar designation.

Culvert spans 6'-0 (1800 mm) and less shall use variable length bent longitudinal (e & f) bars in the slab and floor.

Culvert spans 8'-0 (2400 mm) and greater use details shown to determine reinforcing bar lengths (ie. Series of constant length straight bars and bent bars with variable lap lengths).

1. The length for the straight longitudinal (e & f) bars in the slab and floor is 2 inches (50 mm) clear at barrel joint end and extends in length to where the front face of the short barrel wall bends.
2. The bent longitudinal (e & f) bars in the slab and floor are to lap the straight longitudinal bars with the lap shown from the Table 4.7.4-1 for "other bars".

When the concrete thickness below the bar exceeds 1'-0 (300 mm) use the "top bar" lap from the table to calculate the bar length. There will be one bent bar length each for the top slab, bottom slab, top floor and bottom floor. This will hold for single and multiple barrel sections.

3. Multiple barrel culverts straight longitudinal bars will change length in each barrel as shown in Figures 4.7.4-1 and 4.7.4-2. The bent longitudinal bars will remain one length in all barrels.
4. Normal transverse reinforcing steel patterns shall be maintained to the front face of the shortest barrel wall for each barrel. Additional flared bars shall be added to maintain design spacing at the wall joints and mid-span of the barrel.

4.7.4.2 Barrel lengths

All bent sections shall have equal bend lengths.

The bend shall be 5 degrees minimum and in increments of 5 degrees to a preferred maximum of 15 degrees bend. Bends greater than 15 degrees are allowed as approved by the Preliminary Bridges and Structures Engineer.

6'-0 (1800 mm) and smaller span barrel lengths:

The minimum distance 3'-0 (900 mm) is along the front face of the shortest barrel wall of a bent section. The barrel length is measured along the centerline of the culvert. This minimum short wall length will increase to achieve a barrel length of feet and nearest whole inch (10 mm) in length.

8'-0 (2400 mm) and greater span barrel lengths:

The minimum distance 5'-0 (1500 mm) is along the front face of the shortest barrel wall of a bent section. See Figures 4.7.4-1 and 4.7.4-2. Typically the length of the short wall can be increased to bring the culvert length along centerline to a whole foot increment (100 mm).

This minimum distance bent culvert section shall normally be used when extending an existing culvert and the bend is occurring at the section being joined to the existing culvert. If a bend is used at a location not adjacent to an existing headwall, the maximum culvert barrel length along the centerline of the culvert shall not exceed 38 ft (11480 mm).

Table 4.7.4-1-LONGITUDINAL (e & f) BAR LAPS		
English Bars		
	Top Bar	Other Bars
#4 Bar Lap	1'-6	1'-1
#5 Bar Lap	1'-10	1'-4
#6 Bar Lap	2’-3	1’-7
Metric		
	Top Bar	Other Bars
#10 Bar Lap	390	310
#15 Bar Lap	540	390
#20 Bar Lap	640	490

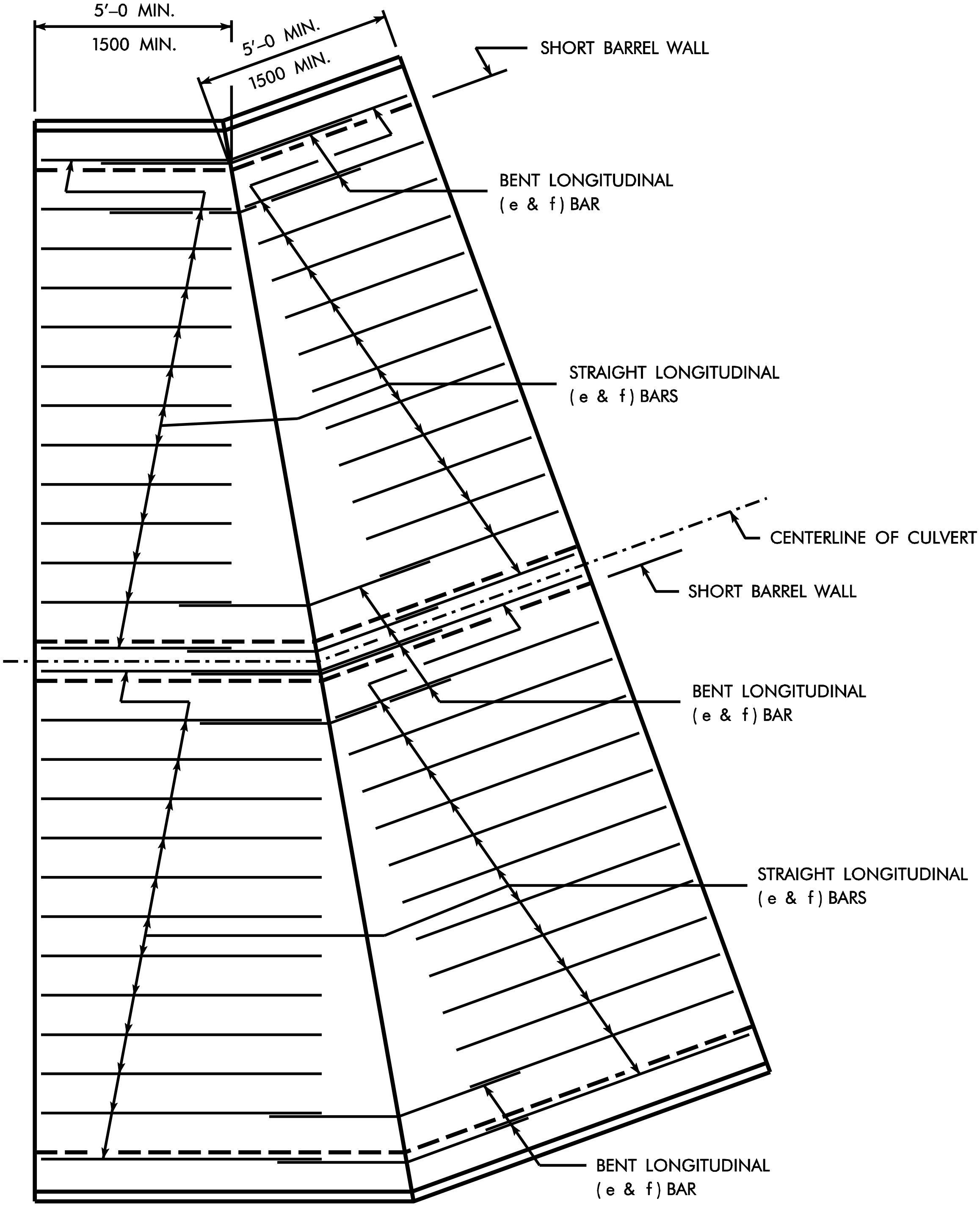


Figure 4.7.4-1
Bent Twin 12 ft. (3600 mm) Span
Example for Longitudinal Bar Bends

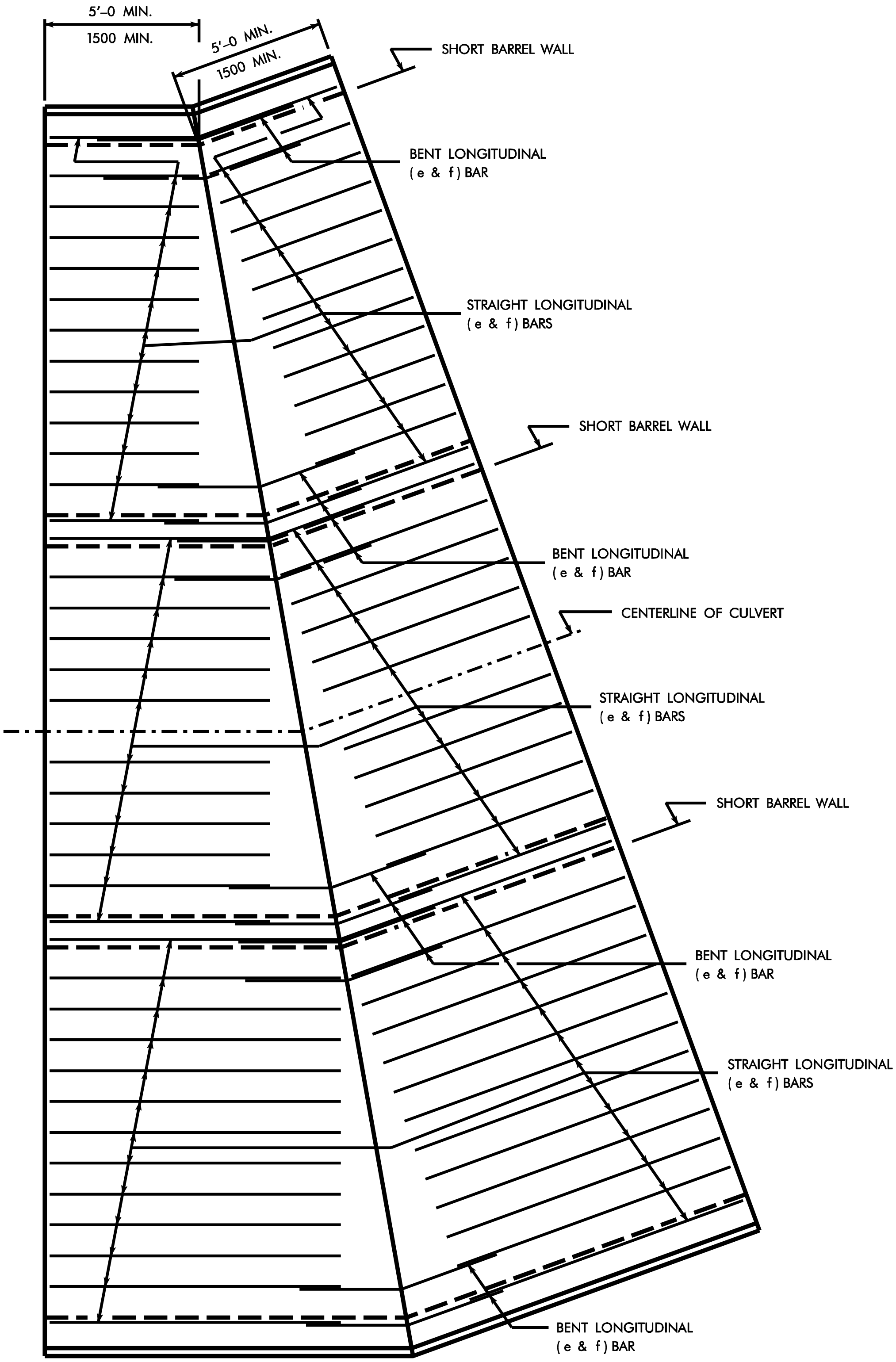


Figure 4.7.4-2
Bent Triple 12 ft. (3600 mm) Span
Example for Longitudinal Bar Bends

4.7.5 Bend Details for Extensions Adjacent to Skewed Headwalls

When detailing barrel bends next to skewed extensions follow the details shown in Figure 4.7.5-1 through 4.7.5-2 along with the guidelines listed below. Transverse bars shall be flared according to the minimum and maximum spacing specified in article 4.7.2.

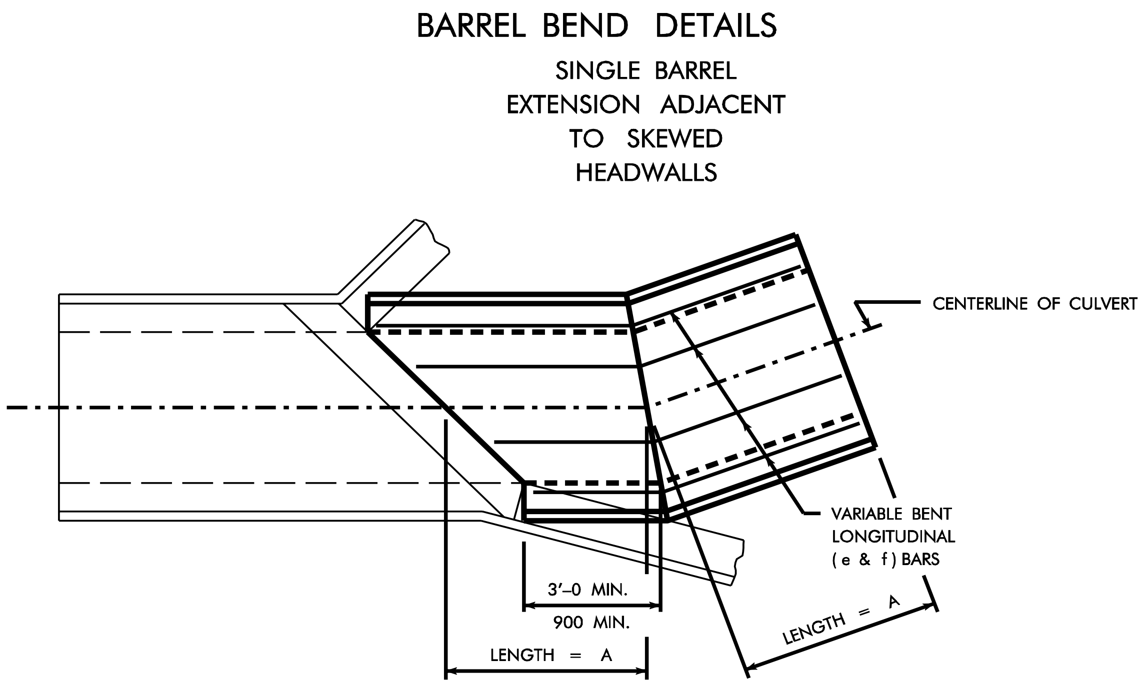


Figure 4.7.5-1
4 ft. (1200 mm) Span Example with 45˚ Headwall

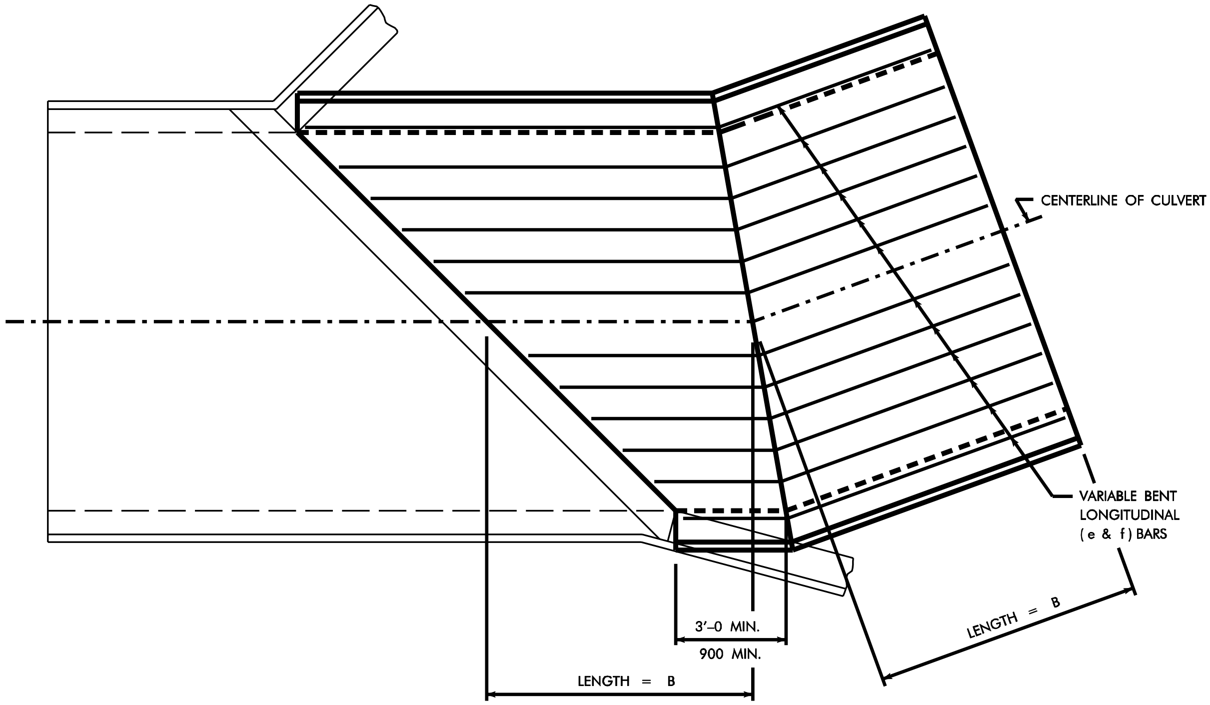


Figure 4.7.5-2
12 ft. (2400 mm) Span Example with 45˚ Headwall

4.8 Reinforced Concrete Box Culvert Standards [8/9/93]

When designers designate the use of the "Single Span Reinforced Concrete Box Culvert Standards", "Twin Reinforced Concrete Box Culvert Standards", or the “Triple Reinforced Concrete Box Culvert Standards” the design fill height must be clearly shown on the plans.

4.9 Reserved

4.10 Scour Floor Details

Scour floor details shall be provided as shown in Figure 4.10-1.

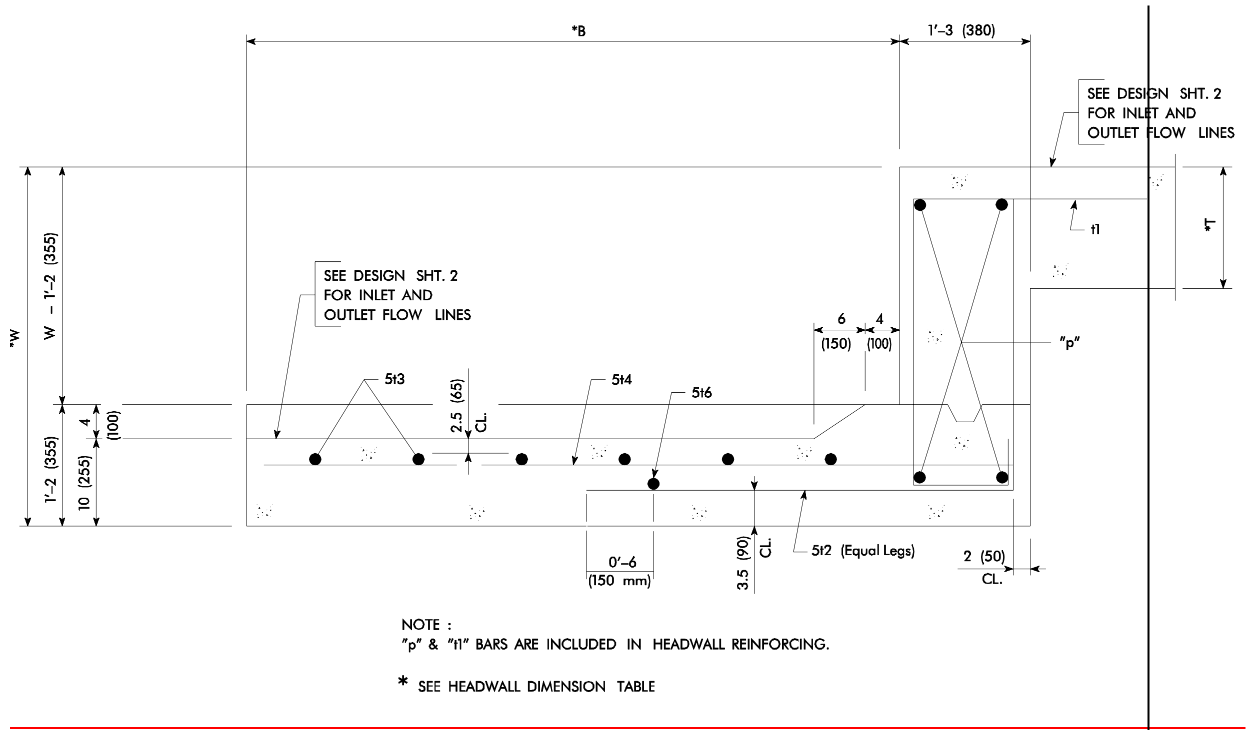


Figure 4.10-1
Section Through Curtain Wall and Scour Floor

4.11 Granular Blanket Sheet [3/11/82]

The Soils Section will make a comment on the estimated settlement sheet concerning whether a granular blanket is required and if needed they will supply the information on the blanket.

The preferred policy is to have the granular blanket installed by the culvert contractor (quantities and details included with the culvert plans). If the granular blanket is to be installed by the road contractor, then a granular blanket detail shall be added to the culvert plans for reference only. See Figure 4.11-1 for details.

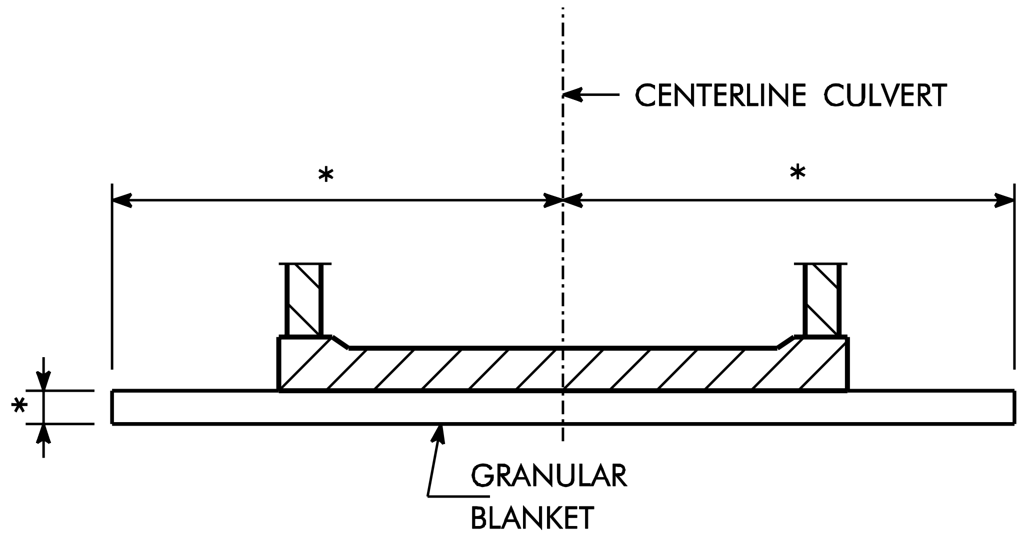


Figure 4.11-1
Granular Blanket Detail
(*Note: Information Provided by Soils Section of Design)

5.0 Pipes and Weepholes

5.1 Pipes Extending Through Walls and Slabs [8/9/93]

Preliminary Bridge will occasionally designate locations where openings for reinforced concrete pipes (RCP's) are to be provided in culvert walls or slab. The office's policy is for the sections to be cast in the wall or slab during the culvert's construction.

For pipes in walls, give the flow line elevation of the proposed pipe, and reference its location with respect to the back face of parapet. For pipes in the slab, reference the location with respect to the back face of the parapet and the centerline of the culvert. The end of the pipe shall extend a minimum of 6 inches (150 mm) past the inside face of the culvert wall. See Figure 5.1-1 for a sample detail. The portion of the pipe that is cast in the culvert shall be incidental to the cost of structural concrete. The item reference list should include the size and length of the pipe. The maximum length of pipe to be cast into the wall should be 4 ft. (1200 mm).

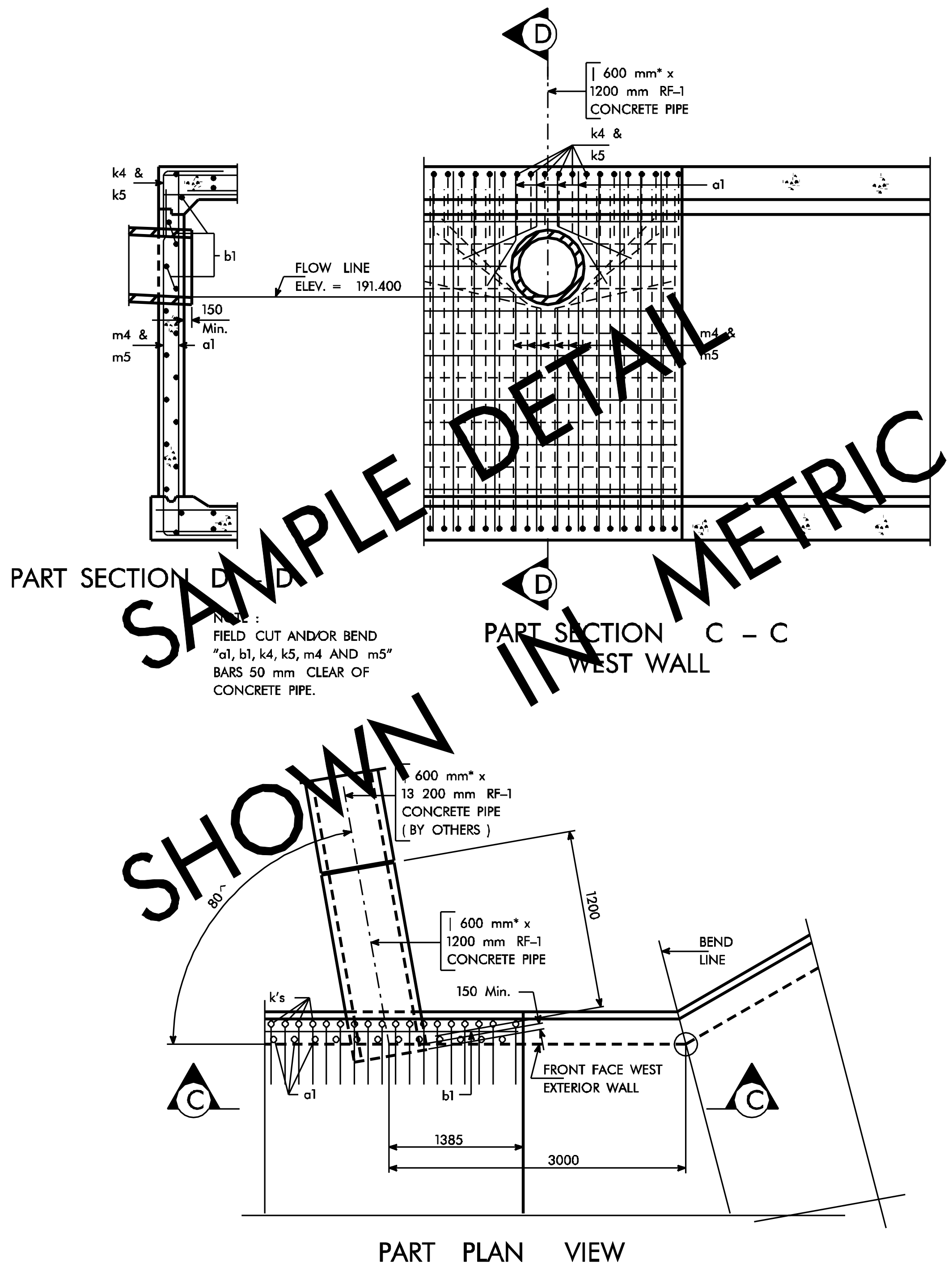


Figure 5.1-1
Sample Details for Concrete Pipes Through Culvert Walls

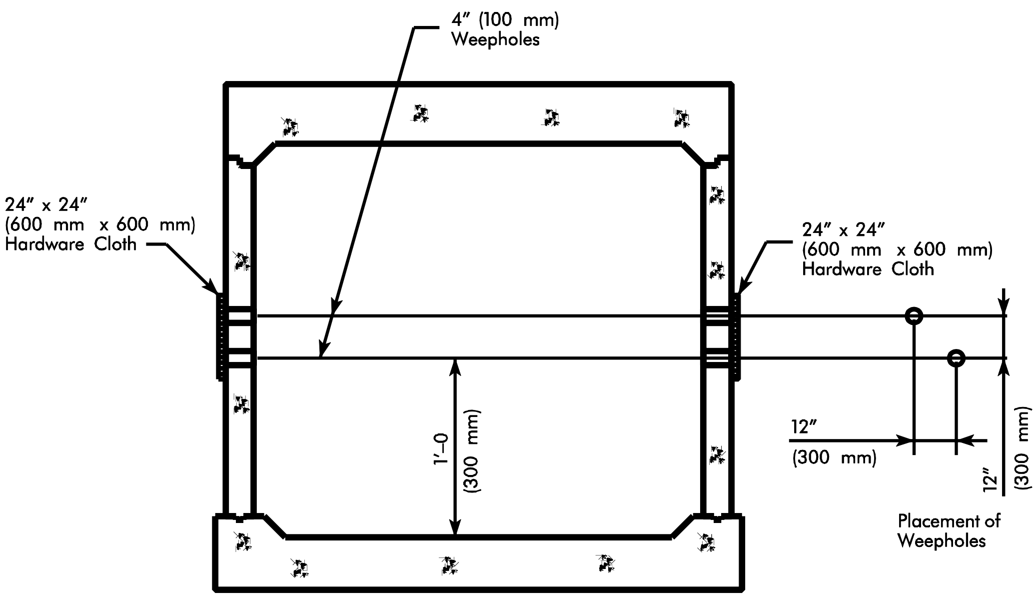
Note: For pipes 48 inches and larger, use reinforcing shown in Figure 6.2-1. Current practice is to put a note on the design plan similar to standard note (E633 and M633).

5.2 Weep holes [8/9/93]

Under certain hydraulic conditions Preliminary Bridge will make recommendations that weep holes be placed in the exterior culvert walls to reduce the hydraulic pressure.

The 4 inches (100 mm) diameter (or square) weep holes are normally placed in pairs, with the bottom hole 1 foot (300 mm) above the flow line. The top hole is placed 1 foot (300 mm) above the bottom hole and offset 1 foot (300 mm). The holes are covered with a rodent screen consisting of a 24 in. x 24 in. x 1/8 in. (600 mm x 600 mm x 3 mm) mesh size, galvanized hardware cloth centered on the weep holes.

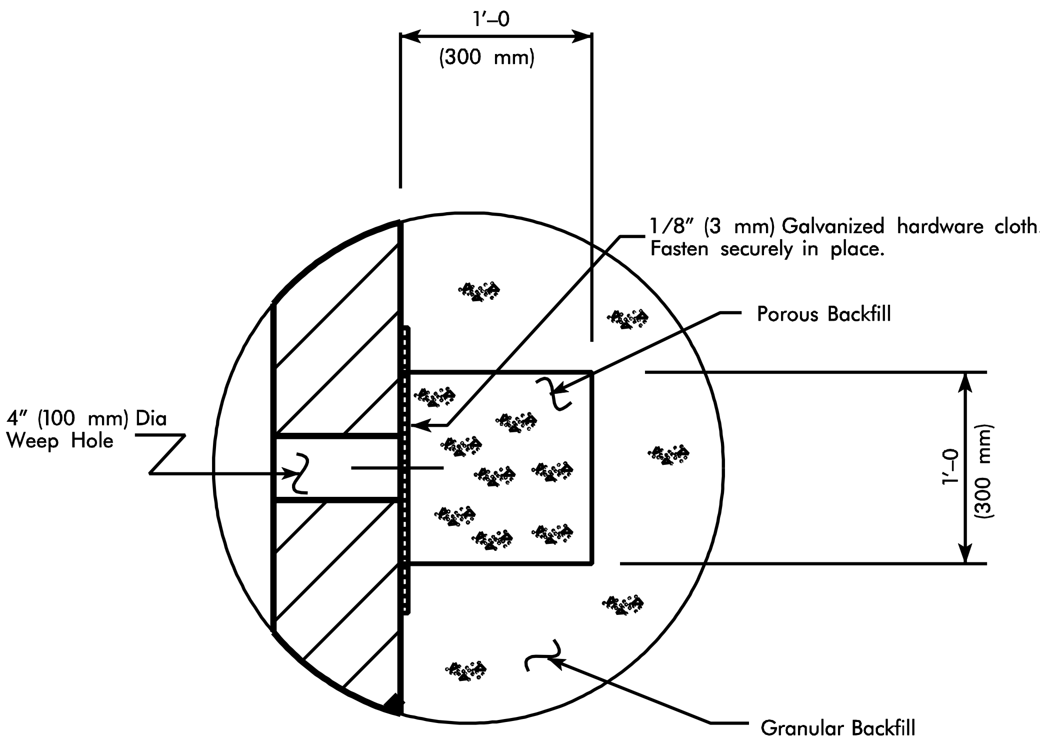
The culvert contractor is normally required to place porous backfill over the weep holes and also furnish and place granular backfill material when completing the Class 20 excavation. See Figure 5.2-1 and Figure 5.2-2 for details.



WEEPHOLE DETAIL

24″ x 24″ (600 mm x 600 mm) 1/8″ (3 mm) Mesh Size, galvanized hardware cloth centered on weepholes. Hardware cloth to be firmly attached to concrete on outside face of walls. Include cost in price bid for concrete.

Figure 5.2-1
Weephole Details



DETAIL "A"

(Typical each weep hole)

Figure 5.2-2
Weephole Details

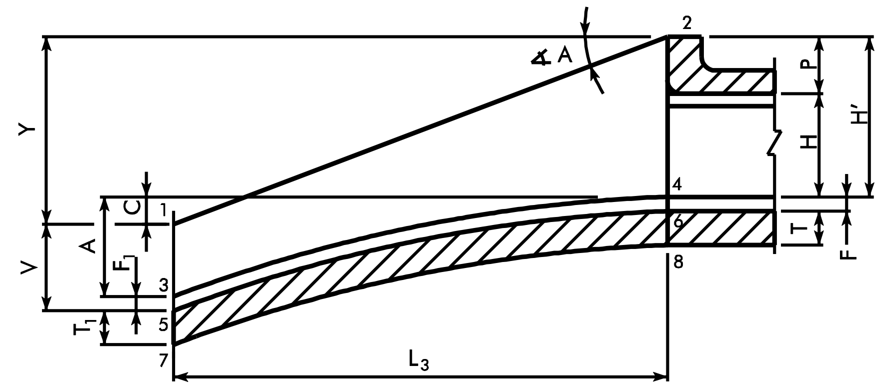
6.0 Flumes [8/9/93]

6.1 General

Flume lengths are designed by Preliminary Bridge and are generally rounded to the nearest 1-foot or the nearest 100 mm. Calculated flume dimensions shall be to the nearest 1/8 in. (5 mm). The flume length and outlet elevation are dependent on the configuration of the site. It is currently standard practice to put a bell joint at the junction of the culvert end barrel section and the flume. Flumes are usually built on embankments where settlement can be expected. See Figures 6.1-1, 6.1-2, and 6.1-3 for details.

For flumes over 40 feet (12 200 mm) in length, bell joints shall also be provided at the mid-point of the flume length; however, the joint should be located past the L_3 length (bottom of the curve).

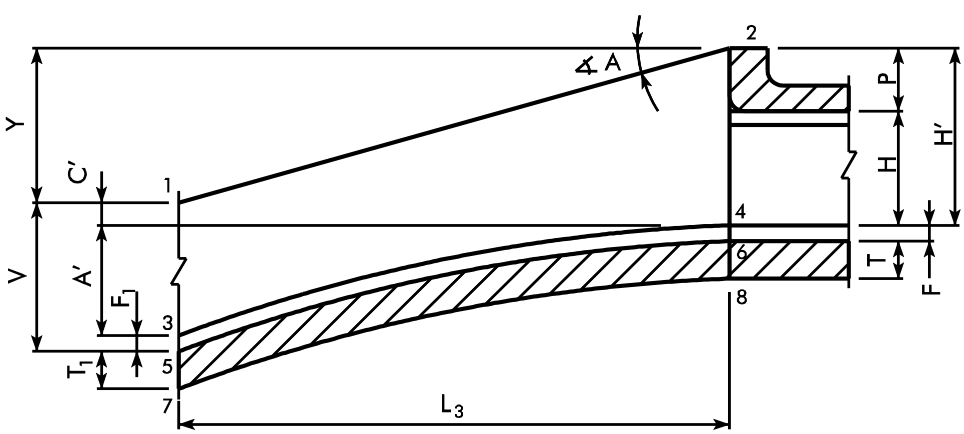
Most flumes have a basin at the outlet end (bottom); however, some flumes are called stub flumes and end with a cut-off wall at the outlet end. Flumes can also be utilized for pipe culverts when appropriate. Note: New flume and basin standards are under development.



$T_1 = T\ (1 / \cos \measuredangle A)$
$F_1 = F\ (1 / \cos \measuredangle A)$
$V = M\ (1 / \cos \measuredangle A)$
$Y = L_3\ (\tan \measuredangle A)$
$C = Y - H'$
$A = V + C - F_1$

AREA 1 = 1, 2, 3 & 4
AREA 2 = 3, 4, 5 & 6
AREA 3 = 5, 6, 7 & 8
AREA 1 = $L_3\ (H' + A/3 + Y/2)$
AREA 2 = $L_3 / 3\ (F_1 + 2F)$
AREA 3 = $L_3 / 3\ (T_1 + 2T)$
AREA = SQ. FT. ONLY

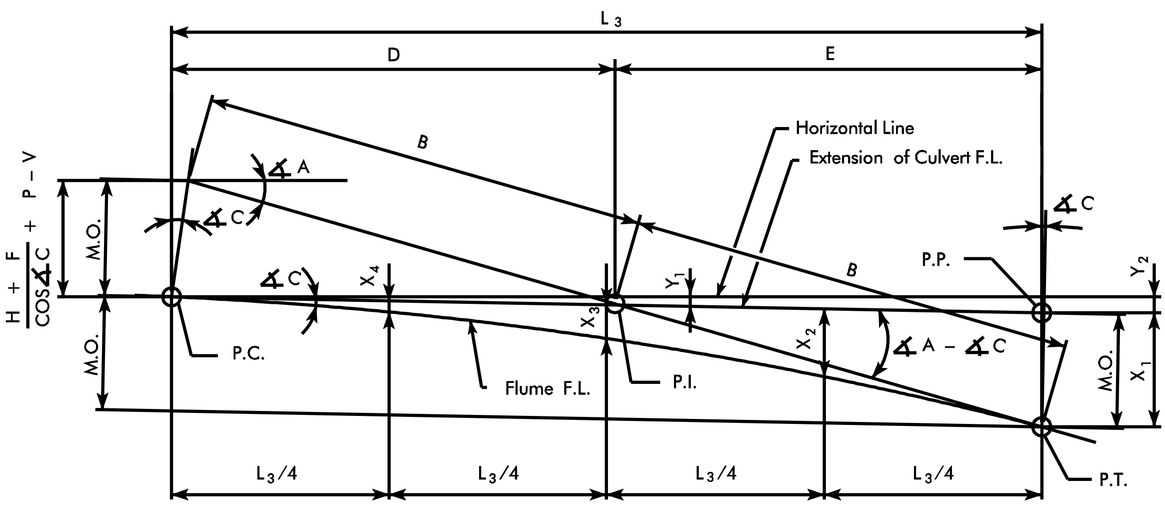
Figure 6.1-1
Estimating Area for V Section for Reinforced Concrete Flumes
(When L_3 is greater than H′)



$T_1 = T\ (1 / \cos \measuredangle A)$
$F_1 = F\ (1 / \cos \measuredangle A)$
$V = M\ (1 / \cos \measuredangle A)$
$Y = L_3\ (\tan \measuredangle A)$
$C' = H' - Y$
$A' = V - C' - F_1$

AREA 1 = 1, 2, 3 & 4
AREA 2 = 3, 4, 5 & 6
AREA 3 = 5, 6, 7 & 8
AREA 1 = $L_3\ (H' + A'/3 - Y/2)$
AREA 2 = $L_3 / 3\ (F_1 + 2F)$
AREA 3 = $L_3 / 3\ (T_1 + 2T)$
AREA = SQ. FT. ONLY

Figure 6.1-2
Estimating Area for L_3 Section of Reinforced Concrete Flumes
(When Y is Smaller Than H′)



PARABOLIC CURVE

$$M.O. = \left[\frac{H + F}{\cos\angle C} + P - V\right]\frac{\sin\angle(90\text{ deg} - A)}{\sin\angle(90\text{ deg} - C + A)}$$

$$B = \frac{M.O.}{\sin\angle(A - C)}$$

$$E = B\cos\angle A$$

$$D = \frac{M.O.}{\tan\angle(A - C)}\cos\angle C$$

$$L_3 = E + D$$

$$X_1 = M.O.\cos\angle C$$

$$X_2 = 9/16\ X_1$$

$$X_3 = 1/4\ X_1$$

$$X_4 = 1/16\ X_1$$

$$Y_1 = \frac{M.O.\sin\angle C}{\tan\angle(A - C)}$$

$$Y_2 = L_3\tan\angle C$$

H = Height of RCB
P = Depth of Parapet
F = Depth of Frost Trough
V = M (1/COS∠A) (Vertical Height of Chute)
M = 3/4 H

Figure 6.1-3
Parabolic Curve Detail and Equations

6.2 Flumes Connected to Pipes

When a reinforced concrete flume is cast in place at the end of a reinforced concrete pipe the following guidelines shall be followed. The flume should be one of the sizes shown on table 6.2-1. This will allow sufficient wall thickness around the pipe for the cast-in-place collar.

Table 6.2-1 Units Flume Size to use with Reinforced Concrete Pipe					
Pipe Size		Flume Size		Height from flowline to top of parapet	
English (Inches)	Metric (mm)	English (ft. x ft.)	Metric (mm x mm)	English (ft-in)	Metric (mm)
24	600	3 x 3	900 x 900	5'-4	1600
30	750	4 x 4	1200 x 1200	6'-4	1900
36	900	5 x 3	1500 x 900	5'-4	1600
42	1050	5 x 4	1500 x 1200	6'-4	1900
48	1200	6 x 4	1800 x 1200	6'-4	1900
54	1350	6 x 5	1800 x 1500	7'-4	2200
60	1500	8 x 5	2400 x 1500	7'-4	2200
66	1650	8 x 6	2400 x 1800	8'-4	2500
72	1800	8 x 6	2400 x 1800	8'-4	2500
84	2100	10 x 8	3000 x 2400	10'-4	3100

See Table 6.2-1 for flume sizes to use with corresponding reinforced concrete pipe sizes. The flume will slope as shown on the standard plans (pending) and be similar to one attached to a reinforced concrete box. The collar should be a thickness of 1'-0. See Figure 6.2-1 for details.

For skewed alignments 30° and greater with a embankment of 3:1, the flume top of wall slope will be 4:1 to accommodate the skew.

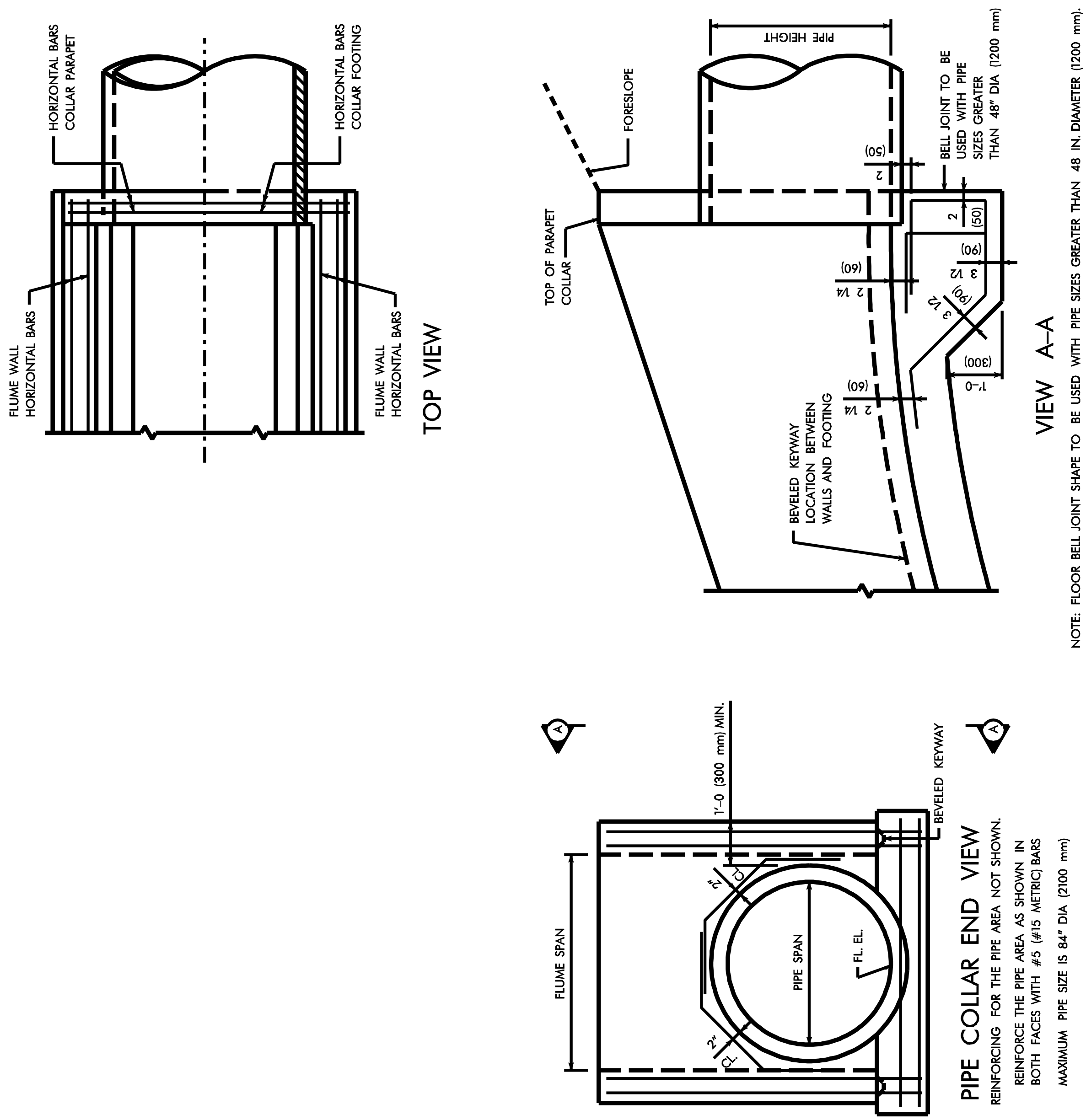


Figure 6.2-1
Flume Details using Standard Reinforced Concrete Pipe

6.3 Reinforcing Detailing

When detailing bent bars where the length of the bottom of the bar and the vertical legs are both greater than 6 feet (1800 mm), the bars may become difficult to ship because of the limited widths of the truck flat beds [8 ft (2438 mm) or less]. Therefore, when you exceed 6 feet (1800 mm) for both the bottom length and vertical leg for the bent bars, break the bar into three pieces and lap as shown in Figure 6.3-1.

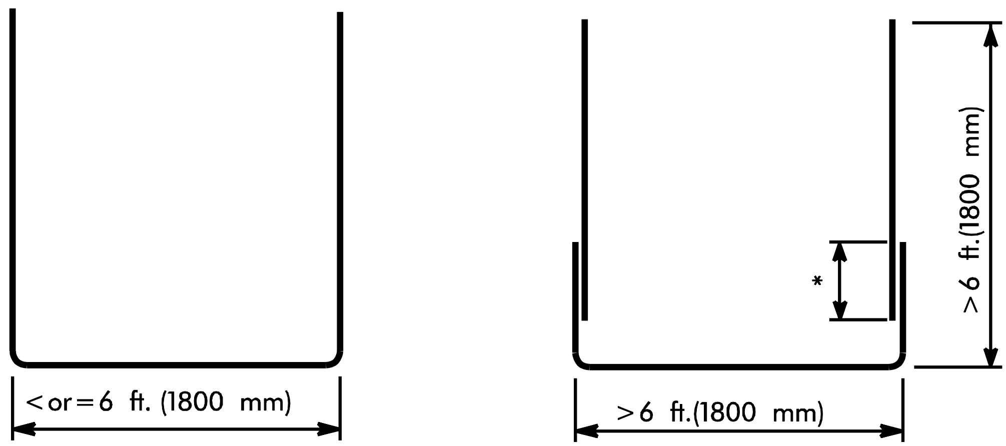


Figure 6.3-1
Length Limits for Bent Bars

*Note: See Table 6.3-1 for lap lengths. Lap is based on a Class C“Other Bars” with a spacing greater than 6 inches (150 mm) and a clear cover in the direction of spacing greater than 3 inches (75 mm).

Table 6.3-1 Lap Lengths	
English	Metric
No 5 = 1 ft. 9 in.	(No 15 = 510 mm)
No 6 = 2 ft. 1 in.	(No 20 = 640 mm)
No 7 = 2 ft. 10 in.	(No 25 = 1060 mm)
No 8 = 3 ft. 8 in.	

6.4 Basins [8/9/93]

Preliminary Design Section normally designs basin floor elevations to be approximately 5 ft. (1500 mm) below the existing streambed. Detailers should check all available soil borings to be sure there is no bedrock at the elevation of the proposed basin. See ~~Figure 6.4-1 for details and Table 6.4-1~~ signed flume standards (RCF-01-04), English units only for flume and basin dimensions.

The “N” distance is less than 5 ft (1500 mm) so the streambed should be 1 ft. (300 mm) to 3 ft. (900 mm) above the end of the flume.

The lengths of the standard stilling basins were reviewed in June, 2002 by the Preliminary Design Section in the Office of Bridges and Structures. Based on the methodology established by the Saint Anthony Falls (SAF) stilling basin, it was determined that the lengths of the standard stilling basins are hydraulically sufficient. The basin is based on 4:1 slope even though flumes can be based on 3:1 or 4:1 slope.

~~Figure 6.4-1~~
~~Flume Details~~
~~Note: Angle A may be a 3:1 or 4:1 slope~~
Figure 6.4-1 Flume Details voided. See signed flume standard (RCF-01-04) for details.

~~Table 6.4-1 Standard Flume Sizes and Dimensions~~ Table 6.4-1 Standard Flume Sizes and Dimensions voided. See signed flume standard (RCF-01-04) for details.

7.0 Excavation, Fill, and Compaction [8/9/93]

Current Iowa DOT Standard Specification covering class 20 excavation for new culverts requires that the excavation be computed using a width 2 feet (600 mm) greater than the width of the culvert footing and side slopes of 1:1.

In addition when computing class 20 excavation for culvert extensions, the quantity is to be computed using a width 2 feet (600 mm) greater than the width of the culvert footing and vertical planes parallel to the boundaries of the structure. When detailing long extensions, for roadway reconstruction where additional lanes are added and the amount of class 20 excavations would be similar to new culverts, the excavation should be calculated as described in the paragraph above. In addition, notes shall be included in the plans describing how the class 20 excavation is calculated.

Occasionally low areas will exist in the area of the proposed culvert. If these areas are large the Road Contractor is normally required to place class 10 fill before the culvert contractor is allowed to begin construction. If these areas are relatively small a note is put on the plan requiring the Culvert Contractor to fill and compact the area. When this work is accomplished by the Culvert Contractor it can be designated as being incidental to the bid item "Class 20 Excavation", assuming there is adequate suitable class 20 excavation available. If there is inadequate suitable class 20 available, the bid item “Class 24 Excavation” is required to provide fill material. See Figure 7.0-1 for details. These excavation limits may not be applicable for special situations such as rock excavation or where granular blankets are used.

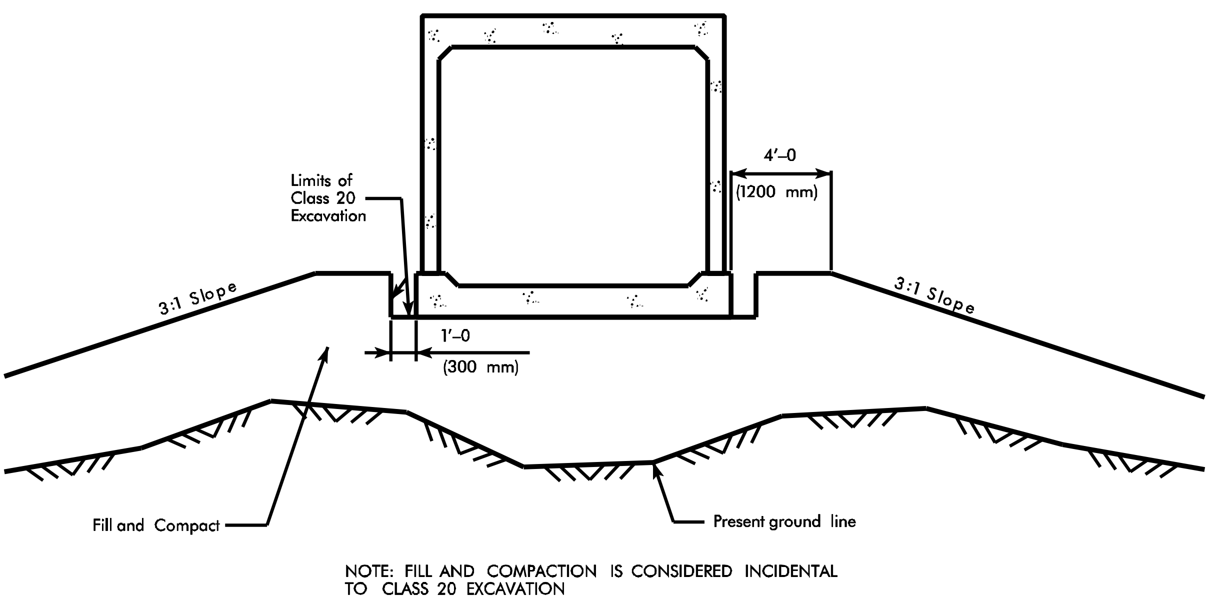


Figure 7.0-1
Fill and Compaction Detail

(Typical Section Normal to Culvert)

8.0 Culvert Extensions

8.1 Design and Standards [8/9/93]

At sites where the shoulder slopes are being improved for safety reasons or when additional traffic lanes are being added, culverts must be replaced or extended. Two Office of Bridges and Structures standard sheets (1043, M1043, 1044, M1044 and M1055) have been approved for use when extending single box culverts. As a general rule the extension should be designed for the maximum height of the fill (either existing fill or new fill) and an HS20 (MS 18) live load. This will ensure that the extension will be adequately designed, should the roadway be widened again at some future date. See Article 3.4.1 "Design Fill Heights" for guidelines for selecting fill depths for culvert extension designs. For 0 degree skewed culverts standard 1044 (M1044) does not need to be used.

Note that if the top of slab is to be used to carry traffic,the slab must be designed accordingly and the slab steel must be epoxy coated. Also paving notches should be added to the walls, in the area of the approach pavement. See Article 4.2 "Culverts with 0 Fill" for additional information.

Occasionally when skewed culverts are extended the transverse bars and corner bars are to be placed parallel to the skewed headwall. When this occurs, the increased span length must be accounted for in the design.

See also "4.3.7 Single Culvert Modifications" for culvert extensions.

8.2 Culvert Extension Reinforcing [8/29/91]

This is in reference to Office of Bridges and Structures standard sheets 1043 (M1043) and 1044 (M1044). Please note that removals for culvert extensions require a 2 1/2" (65 mm) deep saw cut along the front face, top and back face of the wings as well as across the top of the apron floor. Since this saw cut would cut off most reinforcing steel, the existing longitudinal reinforcing will not be incorporated into new work. 5/8" x 2'-6 (15 mm x 760 mm) dowels with a minimum embedment of 10 inches (250 mm) are required to connect the culvert extension to the existing culvert floor, slab, and walls. This change was based on suggestions by the Office of Construction as a way to improve the quality of the joint between new and old work. See Figure 8.3-1 for Extension Details.

8.3 Extension Details [1/31/00]

The details shown in Figure 8.3-1 through 8.3-5 shall be used for connecting new culvert extensions to existing culverts. The flowlines shall match at the joint between the existing culvert and the extension. A plan view and elevation view similar to those shown below will be required on the plans when transitions are used for the wall or floor. The walls should be used to set the transition length and the same transition length should be used for the slab. Any dimensional transition required between the existing structure and the extension should be a minimum of 1'-0 (300 mm). For transitions differences between existing sections and new sections greater than 2 inches (50 mm), make the transition in a 1:6 slope or flatter. For transitions over 3 feet (900 mm) check with your section leader for approval. Existing culvert dimensions shall be soft converted from English to metric for metric designs. The connecting dowels shall be spaced as shown in Figures 8.3-1 and 8.3-2.

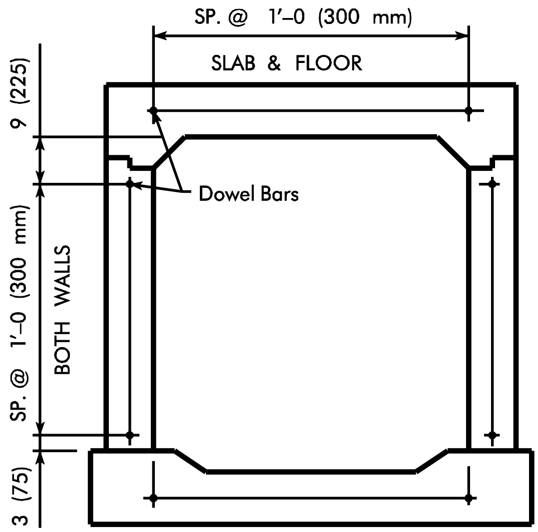


Figure 8.3-1
Section Near Extension
(Showing Spacing of 5/8 in. (15 mm) diameter dowel bars)

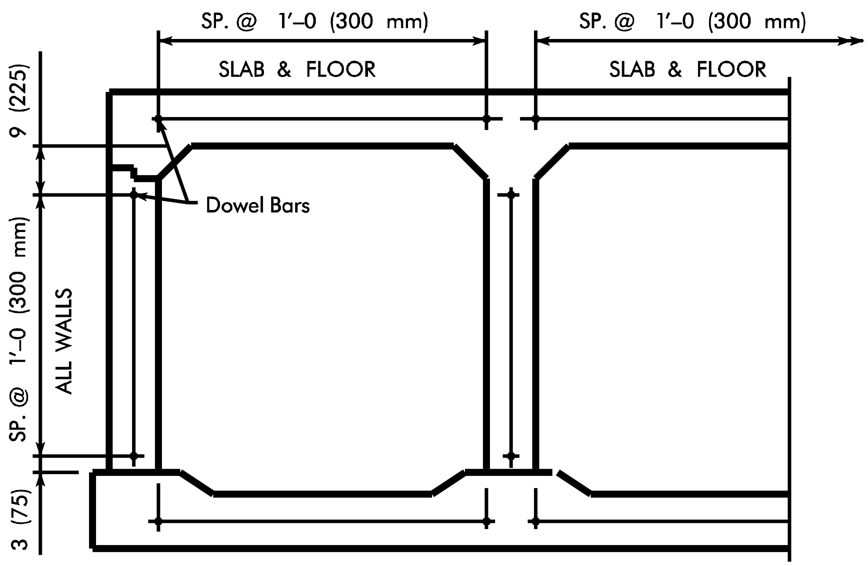


Figure 8.3-2
Section Near Multiple Extension
(Showing Spacing of 5/8 in. (15 mm) diameter dowel bars)

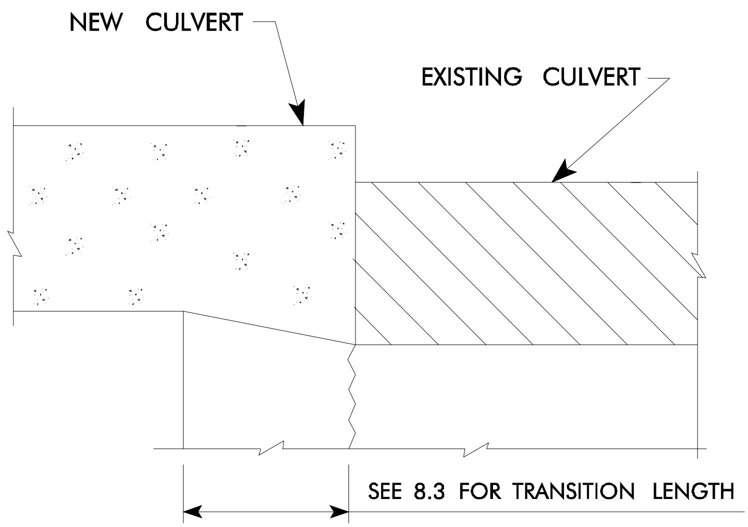


Figure 8.3-3
(Section Through Slab)

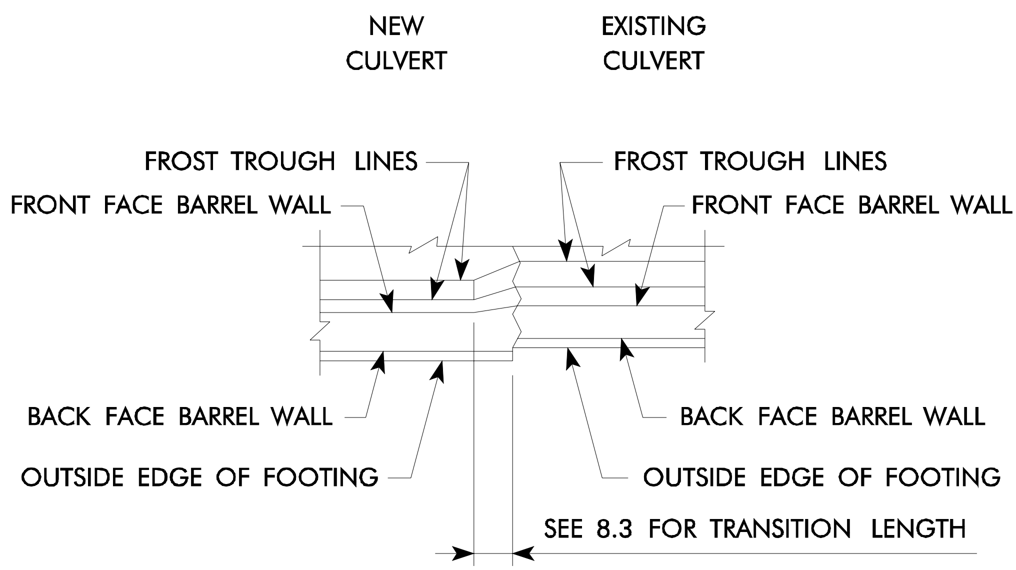


Figure 8.3-4
Plan View of Wall
(Existing Frost Trough Condition)

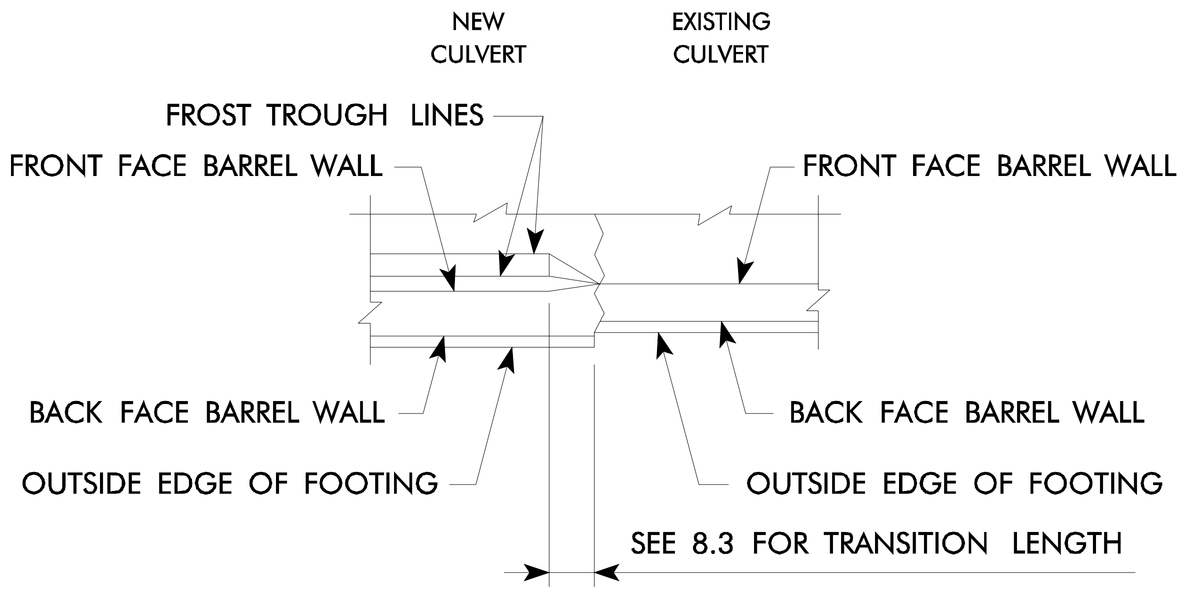


Figure 8.3-5
Plan View of Wall
(No Frost Trough Condition)

8.4 Extensions with Bell Joints

When bell joints are to be used with an extension, a minimum of 5 ft (1500 mm) extension along the centerline or 3 ft (900 mm) along the front face of the short wall shall be provided before the bell joint. See Figure 8.4-1 for details.

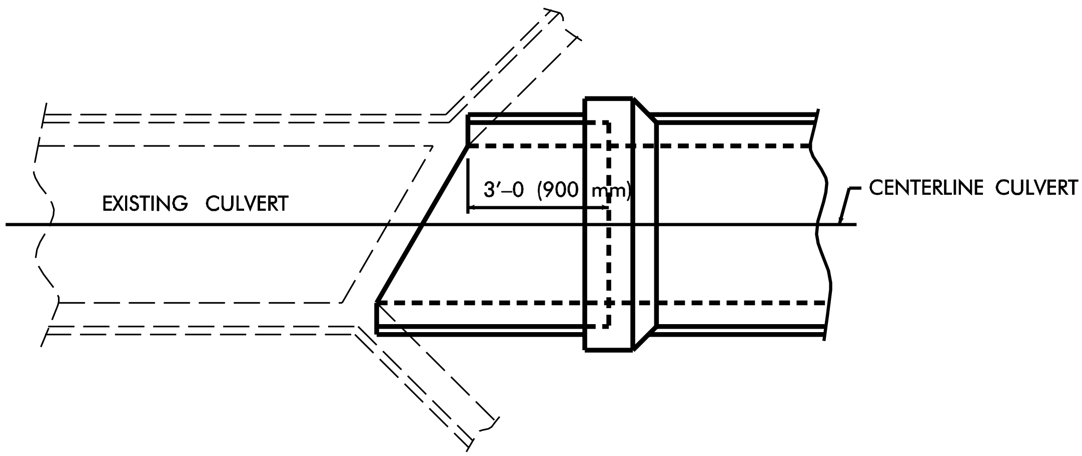


Figure 8.4-1
Plan View Near Extension Junction

8.5 Backfill of Box Culvert Extensions [3/11/88]

Article 2402.09 of the "Standard Specifications" states that:

"For culvert extensions on roads open to traffic, backfilling to the top of the culvert shall be completed within 14 working days after the curing period has expired."

To provide for backfilling to the top of the culvert, it will be necessary to include Road Design Standard Detail 4309 in the culvert plans. This detail will be included in the road plans on the projects where culvert and roadwork is to be accomplished at the same time. When culvert work is to be accomplished with no simultaneous road work in progress, Standard Detail 4309 must be included in the culvert plans. In this case Design will provide the standard detail and all other details and quantities required for incorporation into the culvert plans.

9.0 Flowable Mortar [8/9/93]

9.1 Workspace When Constructing Culverts Under Existing Bridges

Preliminary Bridge occasionally designs box culverts to be placed under existing bridges and then backfilling between the bridge and culvert with flowable mortar.

When this situation exists the Contractor needs to know how much working room is available. Therefore, the elevation of the lowest beam (or slab), on the existing structure, and the top of slab elevation of the proposed culvert, should both be shown on the "Longitudinal Section Along Centerline Culvert". See Figure 9.1-1 for details.

The following clearances should be provided when placing culverts under existing bridges.

1. For bridges with a beam spacing 6 ft (1800 mm) or greater use a minimum clearance of 1 ft (300 mm) between the top of the culvert slab and the bottom of the lowest beams.

2. For bridges with a beam spacing less than 6 ft (1800 mm) use a minimum clearance of 3 ft (900 mm) between the top of the culvert slab and the bottom of the lowest beams.

3. Provided a minimum horizontal clearance of 1.5 ft (450 mm) between existing substructure units (abutment and pier footings) and the new culvert walls.

4. If the depth of flowable mortar is greater than 5 ft (1500 mm), check with the Soils Section for other alternatives.

For situations where the minimum clearances cannot be used, other options may have to be considered such as precast culverts or burying the flowline of cast in place units or bridge replacement. Check with the preliminary design section.

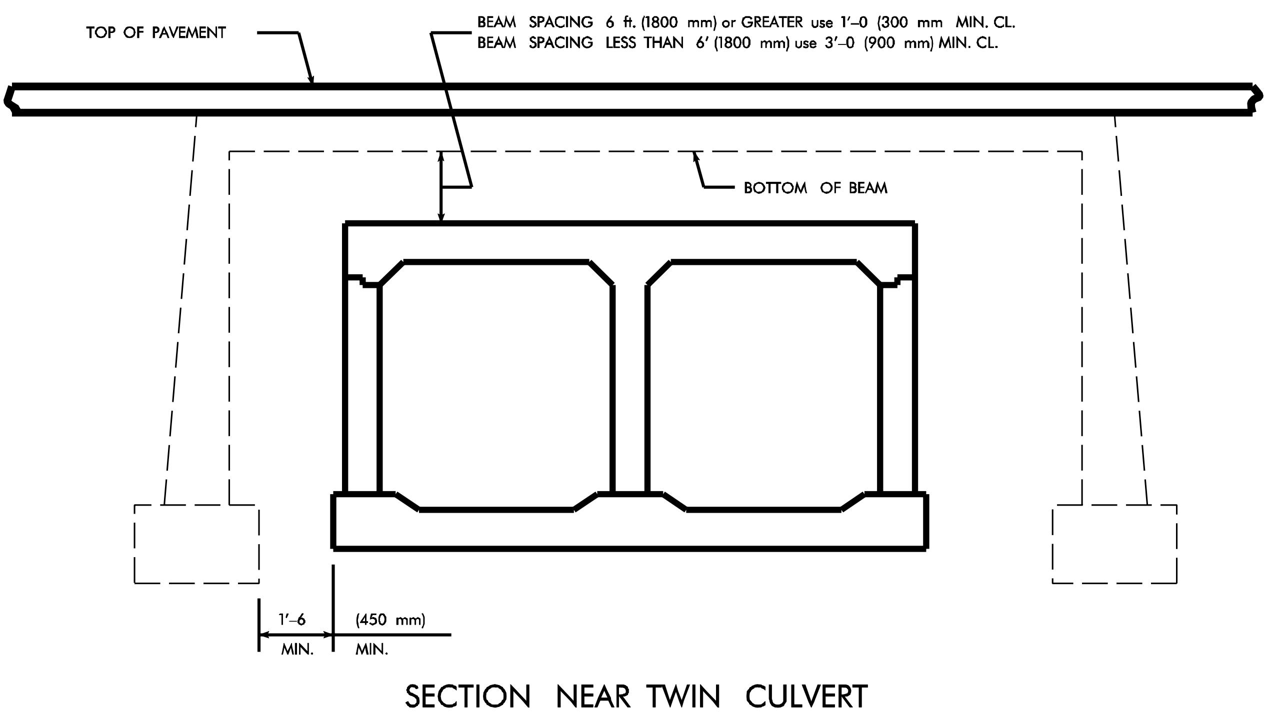


Figure 9.1-1
Clearance Details for Culverts with Flowable Mortar

10.0 Precast

For precast culvert projects see section 8.3 Precast Culverts in the Bridges and Structures Design Manual ~~design manual~~ and check with your section leader for detailing requirements.

11.0 CMP Anchors in Wingwalls [8/9/93]

Preliminary Bridge occasionally designs CMP's or PEP's to be anchored to the tops of wingwalls and flumes. Two bars detailed similar to the 5fa (fa) fence anchors, as detailed on standard "Wingwall Headwall Sheet", should be provided as anchors.

The Contractor responsible for furnishing and placing the CMP shall also be required to furnish and install a ¼ inch (6 mm) diameter galvanized cable over the CMP and clamps to secure the cables.

The plan should indicate the spacing between the anchor bars and the location of the centerline of the CMP with respect to the front face of the parapet. See Figure 11.0-1 for details.

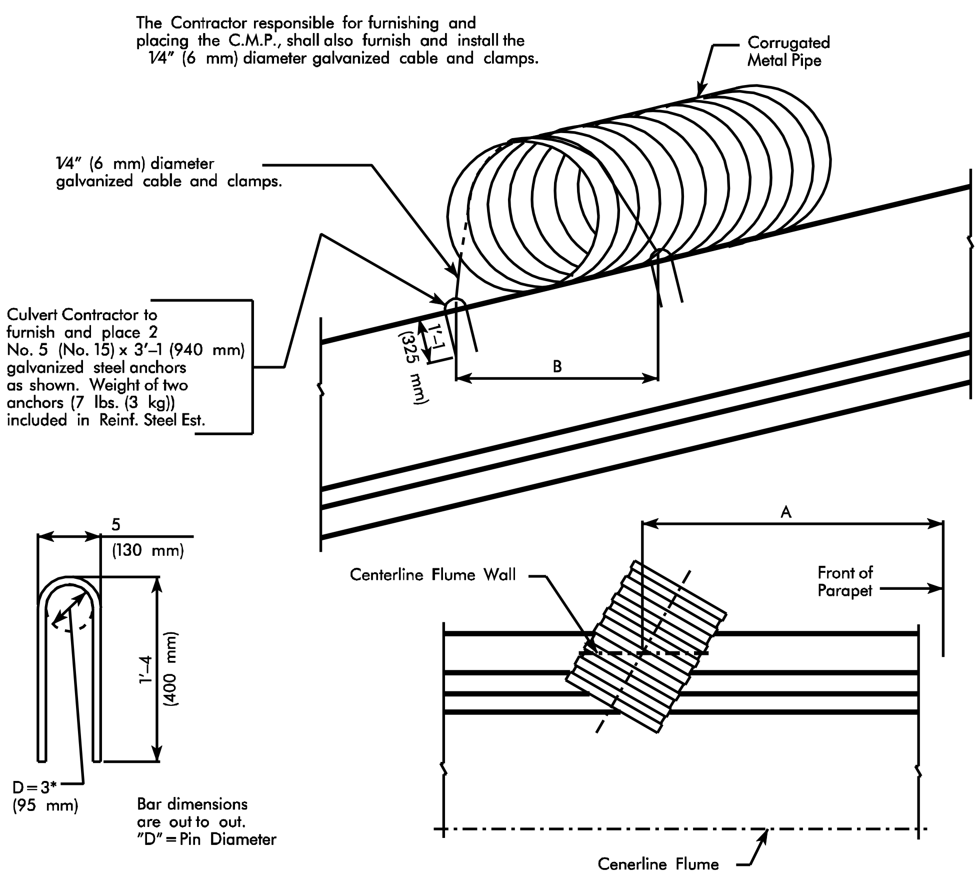


Figure 11.0-1
Corrugated Metal Pipe Anchors

12.0 Debris Racks and Safety Grates [8/9/93]

Preliminary Design Section occasionally design debris racks to be placed over headwalls at the inlet ends of culverts and grates to be placed over the open ends of CMP's and concrete box culverts.

The Office of Materials recommends that debris racks and grates be made with smooth ½ inch (13 mm) diameter (or 5/8 inch (16 mm) diameter) steel bars meeting the requirements of commercial grade M1020. The plan should specify that the racks and grates are to be fabricated before galvanizing.

When detailing debris racks the designers should be aware of the size limitations dictated by the size of available galvanizing tanks. Three tanks are readily available to fabricators as shown in Table 13.0-1

Table 12.0-1 Galvanizing Tanks

	Depth	Width	Length
Valmont Industries of Nebr	7'-2 (2184 mm)	8'-6 (2591 mm)	58'-0 (17 678 mm)
Sioux City, Iowa	5'-0 (1524 mm)	6'-0 (1829 mm)	31'-0 (9449 mm)
Chicago, Illinois	6'-0 (1829 mm)	9'-0 (2743 mm)	51'-0 (15 545 mm)

For examples see Designs 103 Marshall, 397 Crawford County, and 483, 583, and 683 Clayton County.

13.0 Steel Pile Trash Racks [8/9/93]

Preliminary Bridge occasionally designs steel pile trash racks to prevent large trees or other large debris from plugging the inlet end of a box culvert.

The length of the trash rack is governed by the size of the culvert and the width of the stream. Most trash racks are made of HP 10 x 42 (HP 250 x 62) steel bearing piling. The piling are normally driven to a specified elevation and a pile is then bolted to the top of the driven piling with four 7/8 inch (22.2 mm) diameter H.S. bolts at each vertical pile. All bolts and washers are to be galvanized.

Detailers should check all available soil borings for the possibility of bedrock below the stream bed elevation. The piling must be driven deep enough to develop lateral stability.

For example see Design 285 Montgomery County.

14.0 End Wall Details

The details in Figure 14.0-1 and Figure 14.0-2 are to be used when detailing an end wall on a multiple box headwall.

1. The additional quantities for the modification of the interior wall of the headwall are to be included with the end wall quantities.

2. The center wall reinforcing steel from the culvert standard is not to be modified. The displaced concrete area from the center wall is to be subtracted from the end wall concrete quantity.
3. The additional vertical hoops shall match bar size with the vertical "c" headwall bars. The additional horizontal bars shall match bar size with "s" bars from the headwall standards.
4. The Preliminary Design Section of the Office of Bridges and Structures shall determine the height of the wall.

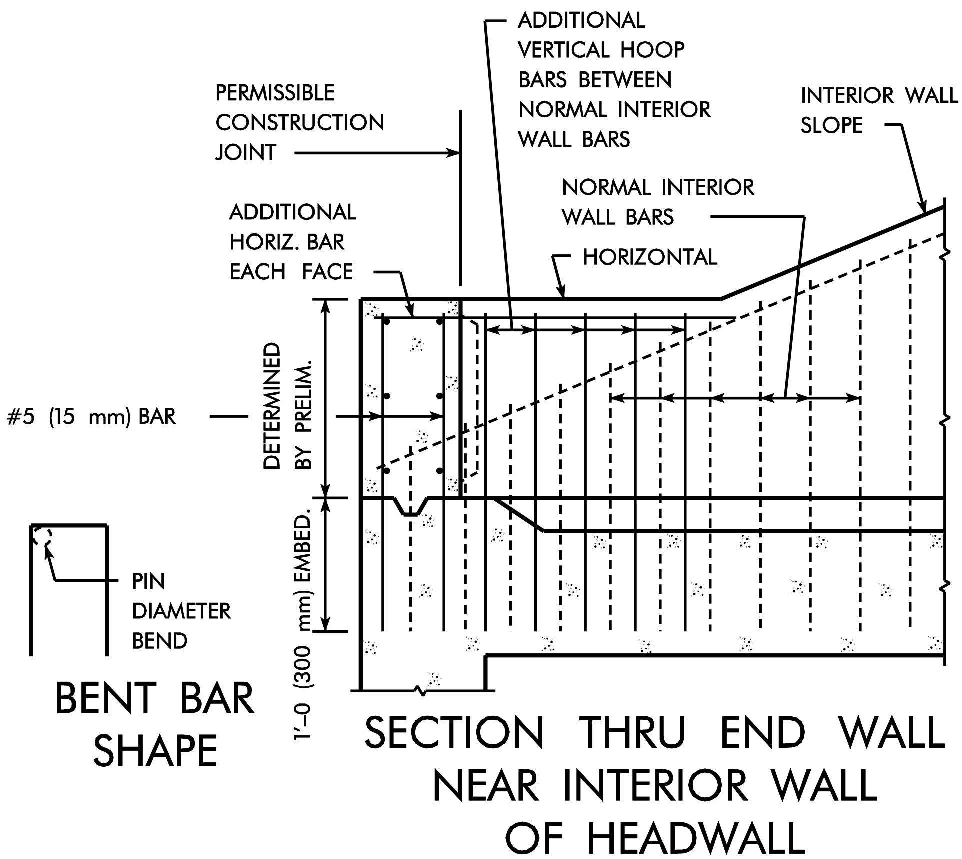


Figure 14.0-1
End Wall Details

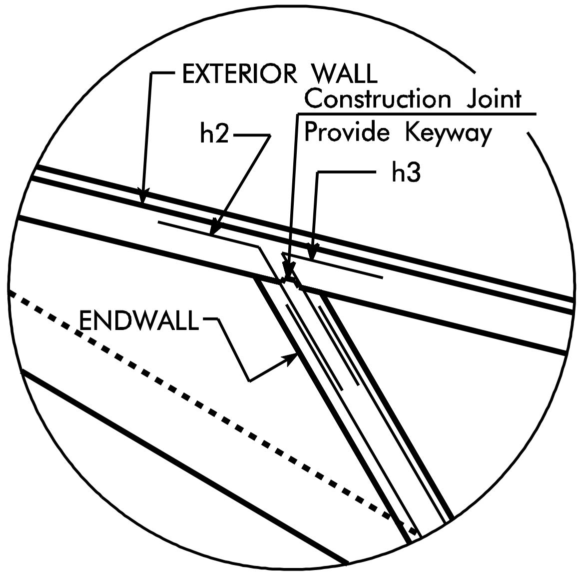


Figure 14.0-2
Detail of End Wall Near Exterior Wall
(Note: Exterior wall bar leg to tie with exterior headwall steel)

15.0 Tapered Inlets [8/9/93]

Preliminary Design Section will occasionally design a tapered section for the inlet end of a culvert in order to improve the flow characteristics.

A tapered inlet is designed for the span at the back face of the parapet and 1 foot (300 mm) of fill. This ensures a conservative design. Bell joints are placed between the tapered inlet and the culvert. 1'-6 (450 mm) of normal barrel size shall be provided at the outlet end of the taper to accommodate placement of the bell joint.

Tapered inlets and flumes are generally used together. See Figure 15.0-1 for details of an English example.

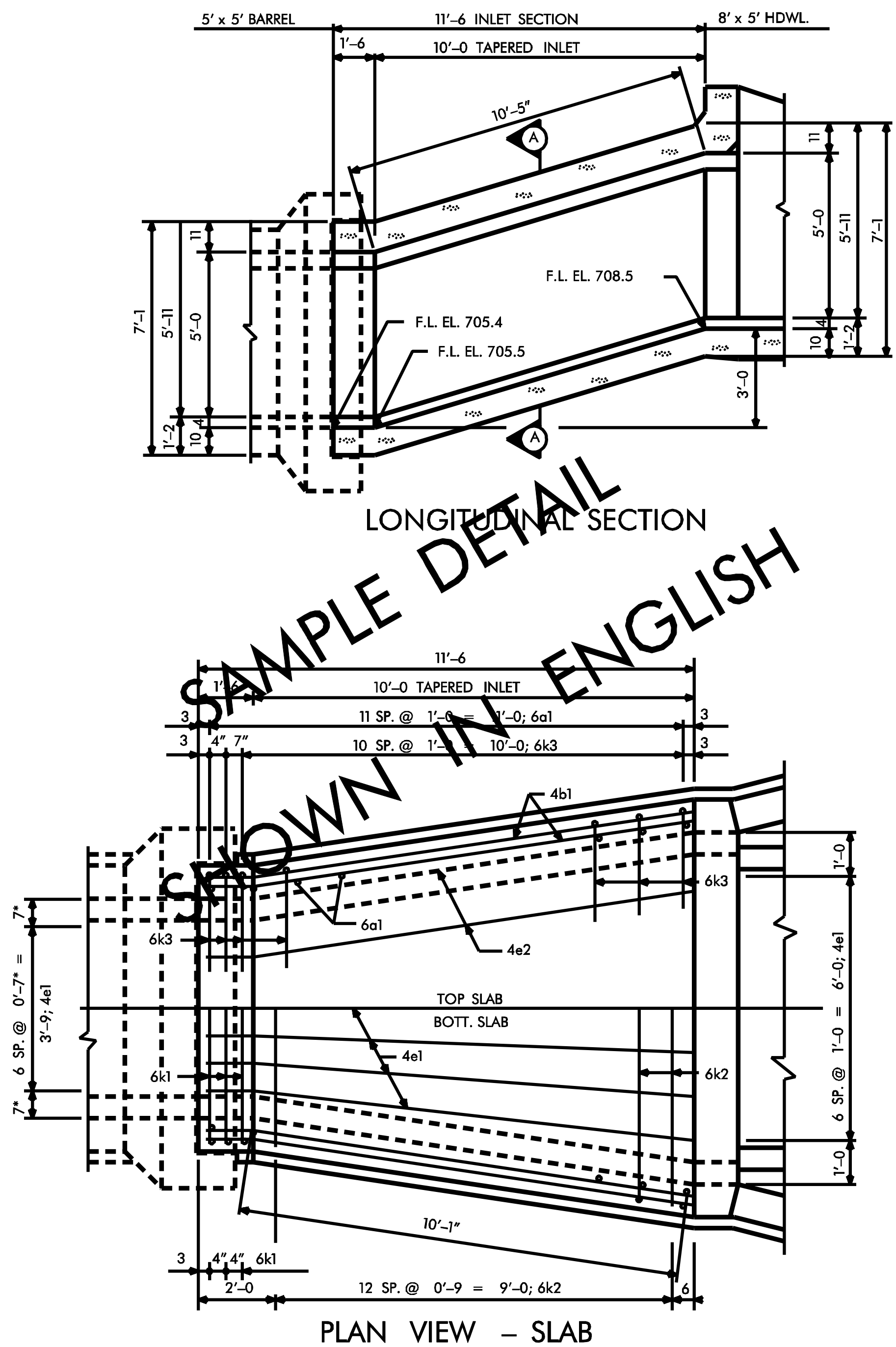


Figure 15.0-1
Example Details of Tapered Inlets

16.0 Miscellaneous

16.1 Pipe Handrails [3/15/95]

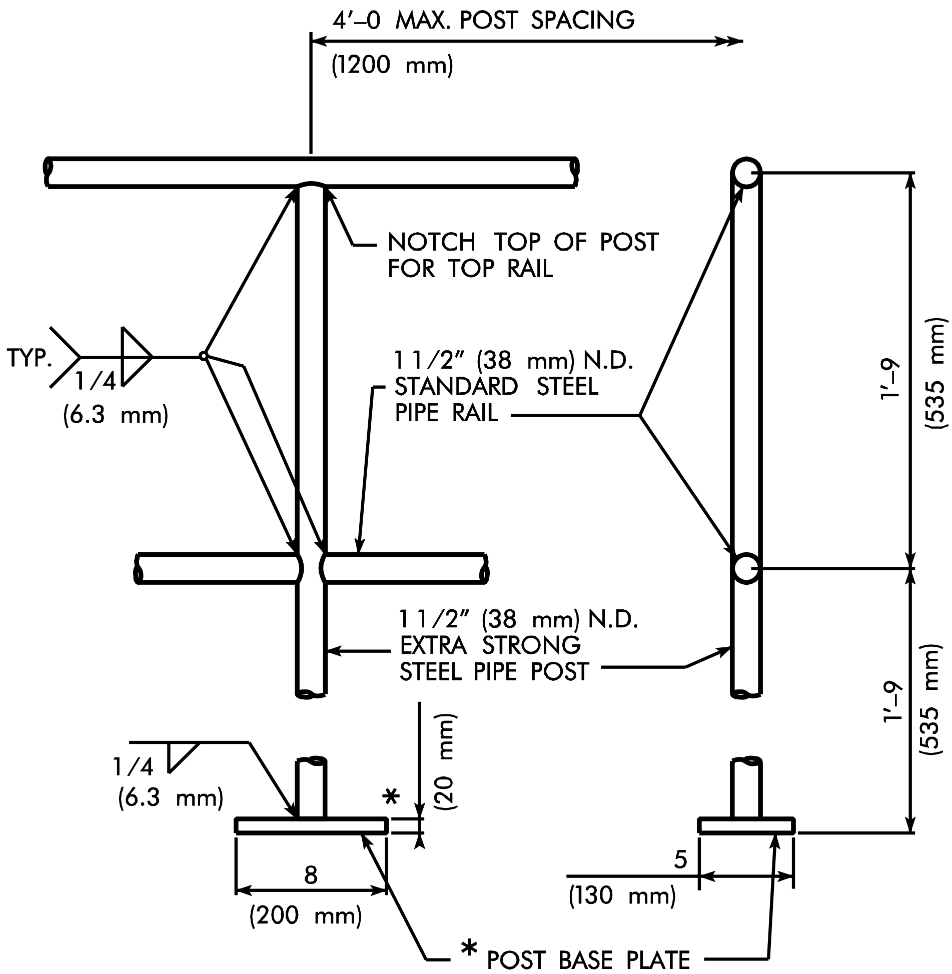
Preliminary Bridge occasionally requires the placement of pipe handrails at the tops of drop inlets and other structures. All posts are to be set vertical. These pipes should be galvanized after fabrication.

The pipe handrails should be detailed with two things in mind. One is the ease of handling and transporting. The other is the limiting size of galvanizing tanks as mentioned under the Article 12.0 "Debris Racks and Grates". The pipe rails should be jointed accordingly.

A 1'-0 (300 mm) embedment of the post into the concrete walls should be used in rural areas. The base plate detail is to be used in urban areas for ease of removal. See Figure 16.1-1, 16.1-2, 16.1-3 and 16.2-3 for details.

The rails should be detailed to show that the centerline of the top rail is to be 3'-6 (1050 mm) above the top of the drop inlet walls and 3'-10 (1150 mm) above the flowline of the weir. The centerline of the bottom rail is to be 1'-9 (525 mm) below the centerline of the top rail.

The method of measurement is the distance from end to end of pipe rail.



PIPE HANDRAIL DETAILS

* POST BASES ARE TO BE USED IN URBAN AREAS, OTHERWISE EXTEND POST 1'–0 (300 mm) INTO THE WALLS OF THE DROP INLET.

Figure 16.1-1
Pipe Handrail Details

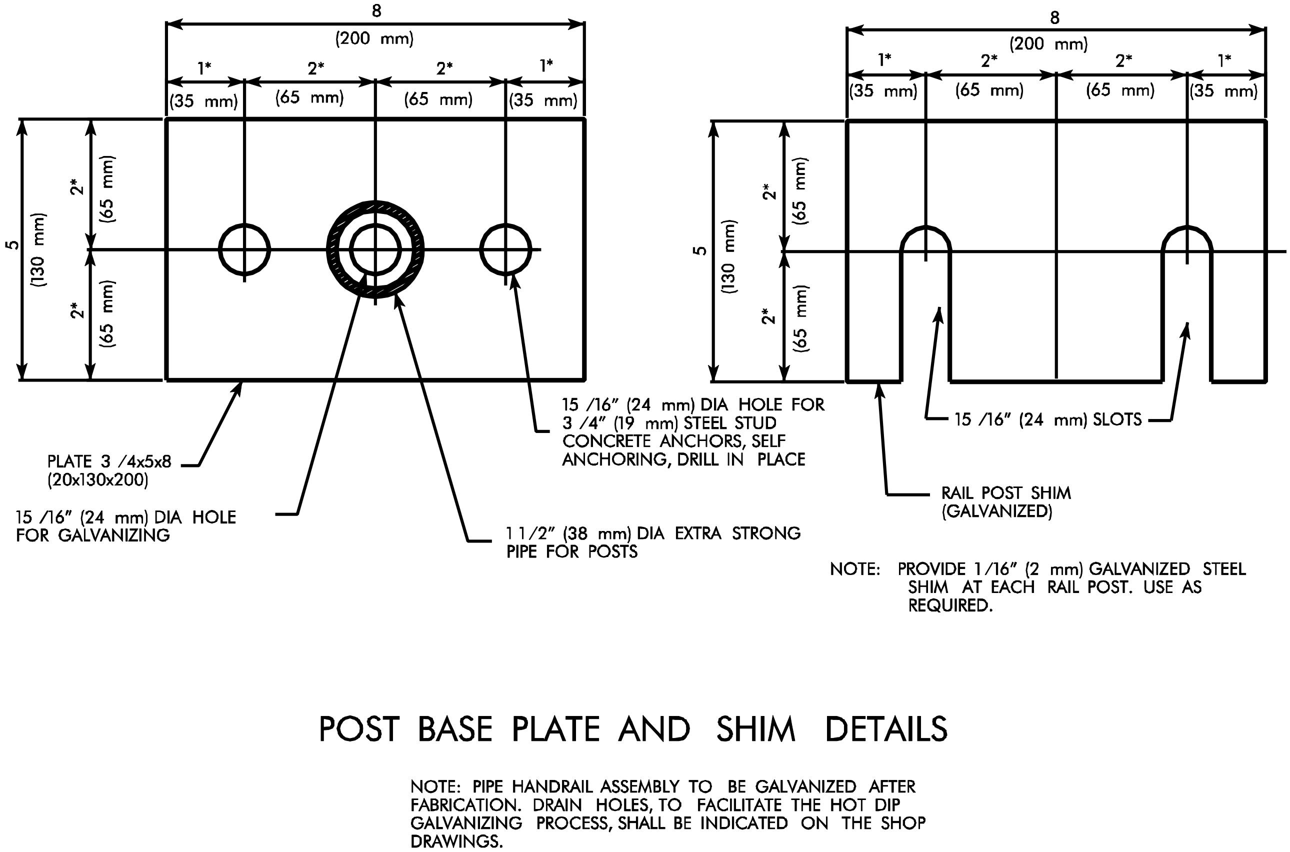


Figure 16.1-2
Post Base Plate and Shim Details

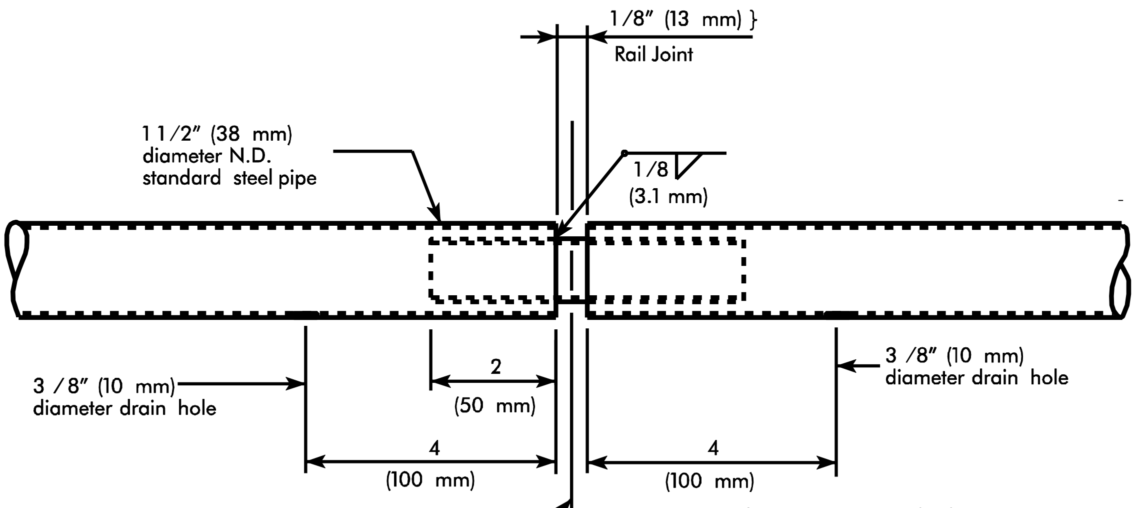


Figure 16.1-3
Rail Joint Detail

16.2 Drop Inlet Wing Determination and Handrail Details

See Figures 16.2-1, 16.2-2, and 16.2-3 for detailing of drop inlets, wing wall lengths and handrail layouts. Details in Figure 16.2-3 are to be used in urban areas where a pedestrian walkway or bicycle path is next to the drop inlet.

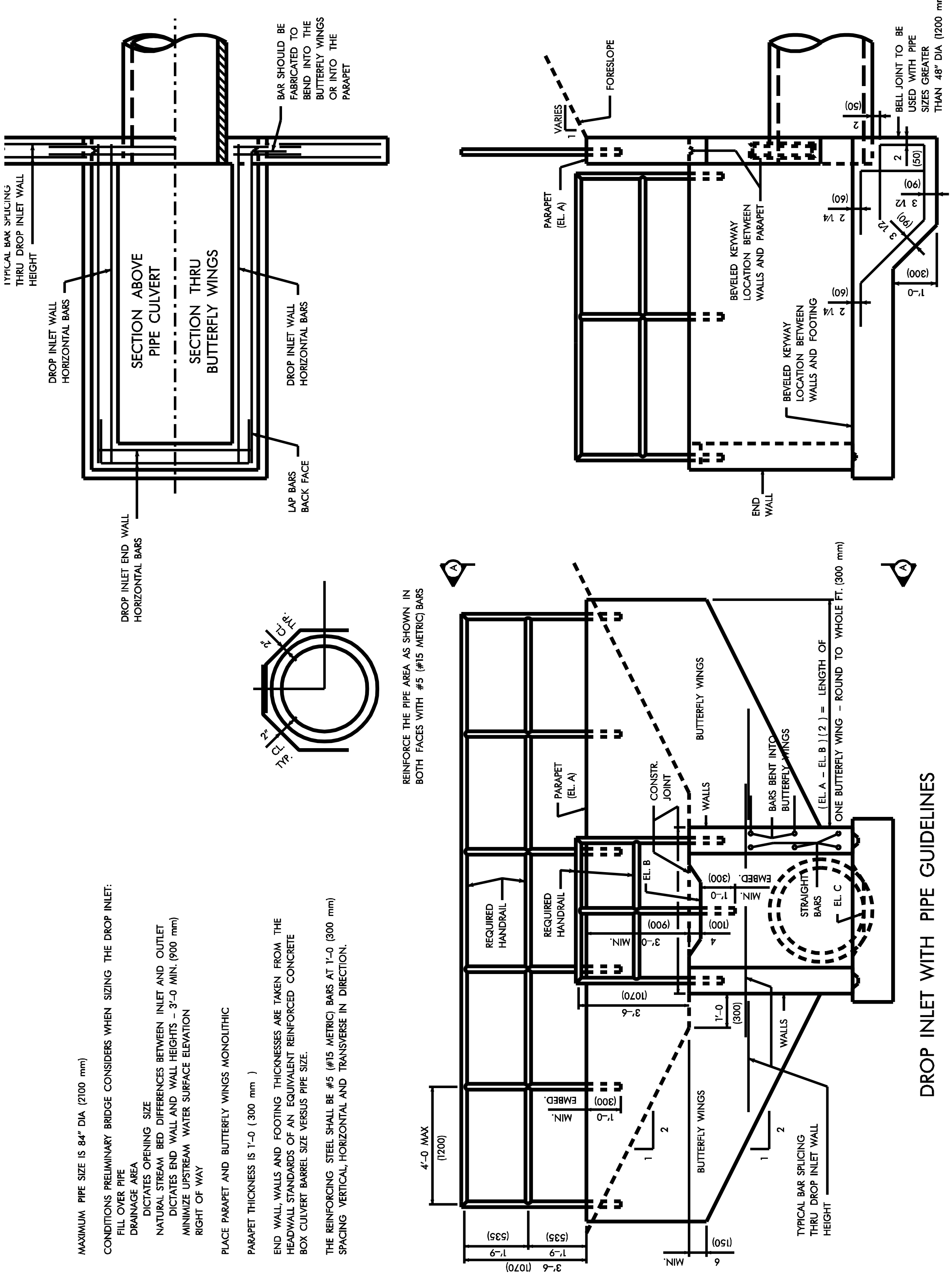


Figure 16.2-1
(Rural Round Pipe)

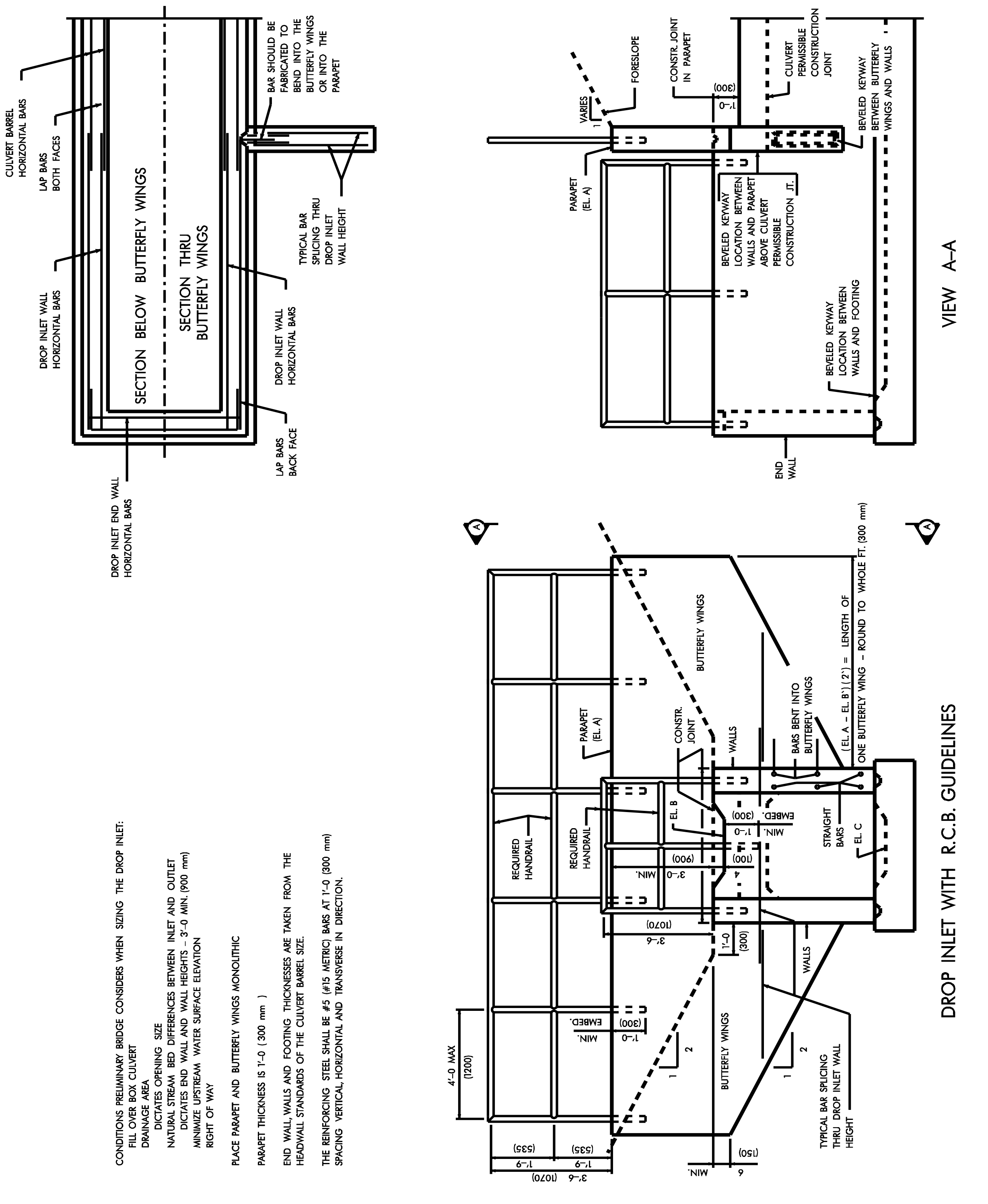


Figure 16.2-2
(Rural Box Culvert)

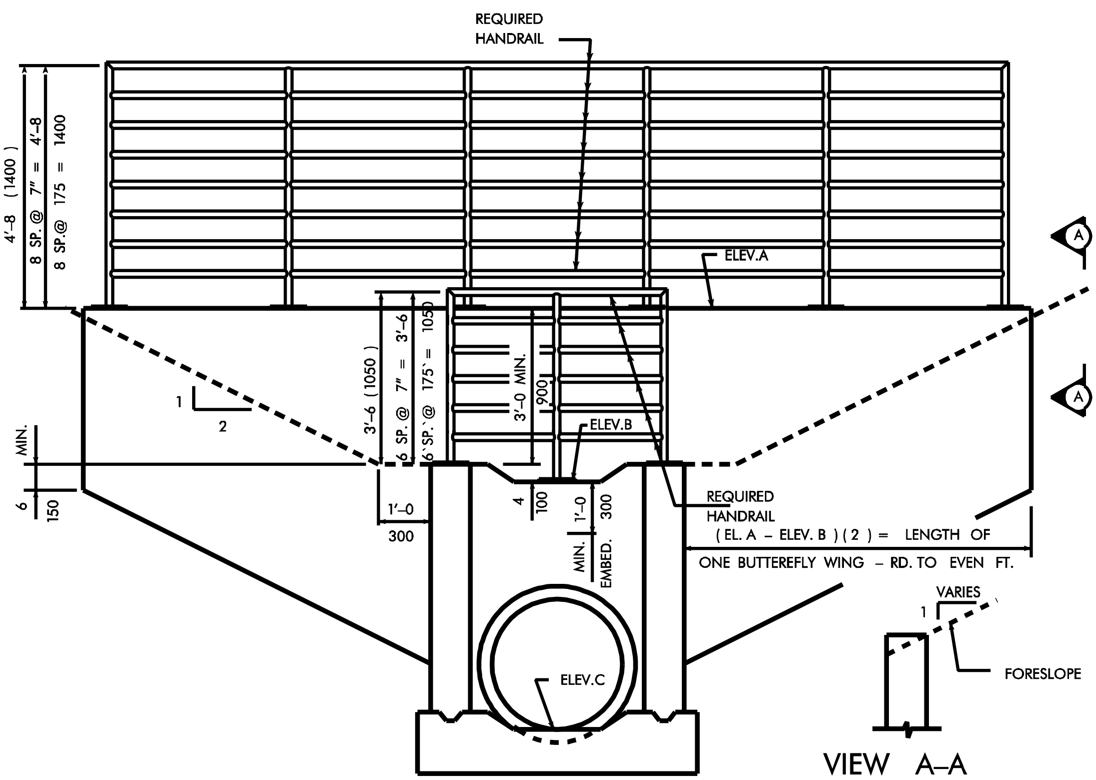


Figure 16.2-3
(Urban Hand Rail)

17.0 Permissible Longitudinal Construction Joints

In some situations where larger multiple box culverts are used and the water flow makes construction difficult, a permissible longitudinal construction joint is provided, so that the floor can be constructed in stages. Guidelines for locating the permissible construction joint are as follows and shown in Figure 17.0-1.

1. Try to place the construction joint outside the short m7 bars.
2. Place the construction joint between the longitudinal bars.

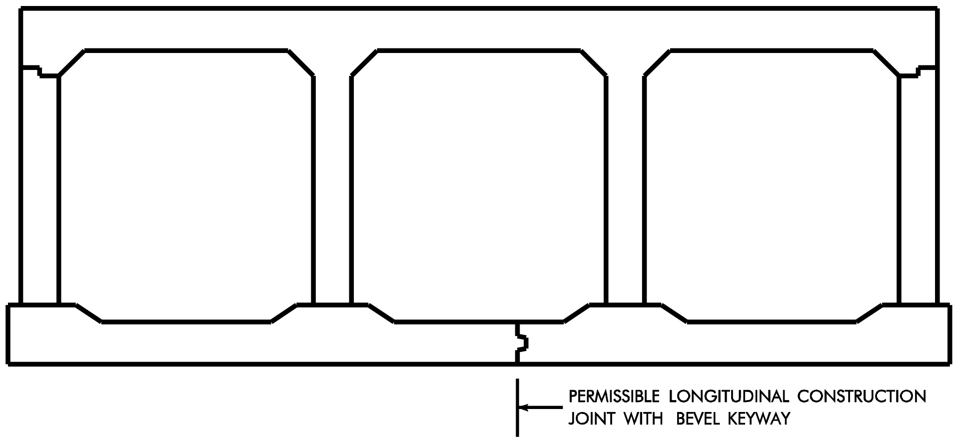


Figure 17.0-1
(Permissible Longitudinal Construction Joints)

18.0 Weirs and Fish Baffles

When required by Preliminary Bridge Section and Department of Natural Resources, weirs and fish baffles may be required on the floors of box culverts See Figure 18.0-1 for example details of a plastic weir.

1. Baffles are placed part way across the culvert floor at and angle specified by Preliminary Bridge.
2. Weirs are placed completely across culvert openings.
3. Weirs or baffles shall not be placed across the culvert joints.
4. When baffles are used a rock splash basin shall be installed at the outlet end of the culvert. See Figure 18.0-1.

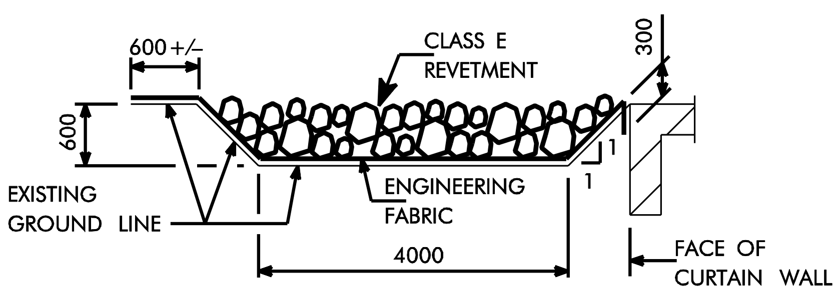


Figure 18.0-1
(Details of Rock Splash Basin)

19.0 Computer Applications

19.1 Mainframe Program for Box Culvert Design [1/28/94]

The programs (single (SIGLBOX) and (MULTBOX) box culvert) were updated to comply with 1993 Interim of the 1992 AASHTO bridge design specifications, which required higher lateral loads in January 1994. For the loads and office policy on earth loading, see "Dead loads and Earth Pressure."

See Appendix C for Input Sheet for The Culvert Program

Additional options that are now included in these programs are as follows:

1. Programs allow for multiple runs using the same size culvert with varying fill heights.

2. Programs have an option for inputting a soil structure interaction factor (Fe), or having the value calculated internally using AASHTO EQ. (17-3). The soil structure interaction factor is necessary for the factor design.

See below for computer input sheet.

Program limitations:

1. SIGLBOX CAN ONLY DESIGN CULVERTS UP TO A 26 FT. MAXIMUM CLEAR SPAN IF THE DEPTH OF EARTH FILL IS EQUAL TO OR LESS THAN 26 FEET. ANY CULVERT WITH A CLEAR SPAN GREATER THAN 26 FEET, AND EARTH FILL <= CLEAR SPAN LENGTH, MUST BE DESIGNED BY MANUAL METHODS. The program (SIGLBOX) only applies two axial loads for live load and is not written to apply the additional axial loads required for longer spans. (>26').
2. MULTBOX can only be used for multi barrel boxes that are symmetrical about centerline of the barrels.
3. For triple culvert designs the center barrel should be at least the same size as the exterior barrels.

19.2 Mathcad File for Design

The following Mathcad files are available for use by the office.

1. Flume Dimensions (English and Metric).
2. Headwall quantities (English and Metric).
3. Bell joint concrete quantity for barrels (English).
4. Flume basin concrete quantity (English).
5. Flume bell joint concrete quantity (English).